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DEPLOY/RETRIEVE STORAGE SYSTEM (DRSS) VOLUME II. PART I. COMPON--ETC(U)
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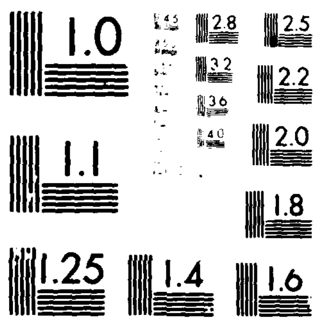
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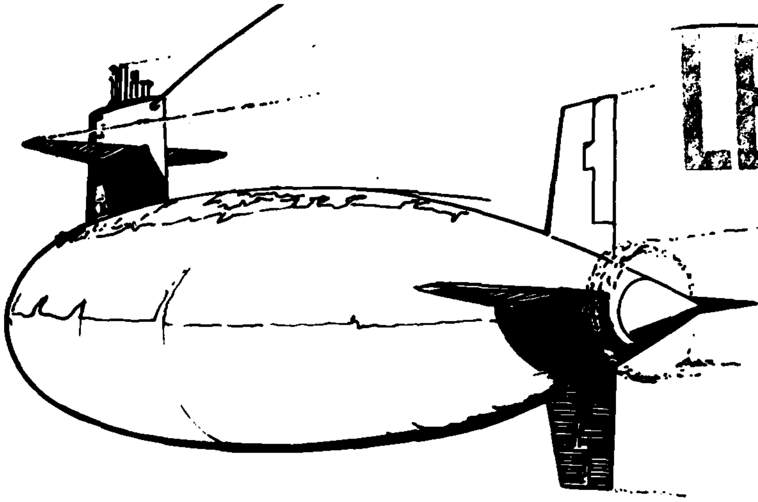
DEPLOY/RETRIEVE STORAGE SYSTEM (DRSS)

VOLUME II
COMPONENT LEVEL DEFINITION AND TRADEOFF ANALYSIS

LEVEL II



SUBMITTED TO:
DEPARTMENT OF THE NAVY,
NAVAL ELECTRONIC SYSTEMS COMMAND
WASHINGTON, D.C. 20360

IN RESPONSE TO:
CONTRACT NO. N00039-79-C-0329

SUBMITTED BY:
GOULD
CHESAPEAKE INSTRUMENT DIVISION
6711 BAYMEADOW DRIVE
GLEN BURNIE, MARYLAND 21061

GOULD

(D)

DEPLOY/RETRIEVE STORAGE SYSTEM (DRSS)

CONCEPT STUDY FINAL REPORT

VOLUME II, Part 1,

SUBMITTED TO:

Department of the Navy
Naval Electronic Systems Command, ELEX 3102
Washington, D. C. 20360

IN RESPONSE TO:

Contract No. N00039-79-C-0329
June 1979 through January 1980

SUBMITTED BY:

Gould Inc.
Chesapeake Instrument Division
6711 Baymeadow Drive
Glen Burnie, MD 21061

Report Number 1 January 31, 1980

AD-A085006

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-ERRATA SHEETS-
DRSS PHASE 1A FINAL REPORT

INTRODUCTION

The following errata sheets contain the Gould, CID response to preliminary NUSC review comments of the DRSS Phase 1A Final Report. There are no changes required to either the conclusions and/or recommendations as a result of the corrections listed herein. The Appendices have not been reviewed.

The format for tabulation of the corrections follows the sequence of volume and section number, with references to the page on which the comments were made. A brief summary opposite the page number highlights the NUSC comment, with an explanation provided under the comments providing the Gould, CID response.

For additional questions and/or clarifications please contact the undersigned.

William R. Richards

William R. Richards
DRSS Project Engineer
Gould, CID
(301)760-3100 ext. 331

AD-A084 006

VOLUME II - SECTION 1

p 10 -- para 4

Change 8.8 PSI to 8.33 pounds/inch (Error in original DRSS Proposal).

p 13 -- para 5(a)

0.5 to 6.0 represents the entire dynamic range required for the transfer mechanism. For requirements only, change 6.0 to 4.0 inches.

p 15 -- para 1.1.4.1

Characterized (typo)

p 22 -- item (1)

Failsafe?

Refer to Vol I, p 25 para 3.2.3 explanation.

Cable Lengths susceptible to buckling?

The outboard dynamic seal, is by its definition, outboard, i.e., -- outboard of the staging tube.

item (3)

Zero slippage?

There can be no slippage as long as the relationship between input/output tension across the deploy/retrieve mechanism is less than that possible due to the coupling mechanism (grip) vs the effective coefficient of friction.

p 24 Figure 1.1.5.4

Highly adaptable to varying cable diameters? (Figure 1.1.5.1a)

A passive loading technique readily adapts to the minimum cable diameter via "spring applied" operation, with its dynamic range capability established by the stroke range of the articulation mechanism. Refer to Appendix A.

-- two point squeeze?

Two-point squeeze is an analogy of a traction belt type system.

A high normal force is required perpendicular to the cable axis of motion.

-- Maintenance is difficult?

Belt replacement will probably be mandatory at normal maintenance intervals due to its potentially low MCBF. Accessibility will be highly restricted, for the configuration depicted.

-- Highly adaptable to varying cable diameters? (Figure 1.1.5.1(b))

Refer to Appendix B.

-- Requires 60 Pinch Roller Assemblies?

Refer to Appendix C.

p 26 -- para 1.2.2	Change the following: Mean Value from 31.95 to 32.42 Std. Dev. from 1.60 to 1.38 Ranking: 33.57 -- no change 32.97 -- to 32.99 32.73 -- no change 30.48 -- to 30.42 30.00 -- to 30.53 and reverse positions of Traction Belt and Laminar Fluid, with Traction Belt being ranked 3rd (along with Laminar Fluid)
p 27 -- Figure 1.2.1(a)	Delete all *
p 28 -- Figure 1.2.1(b)	Delete all * and change the following: Subtotals -- 21.48 to 27.26 23.79 to 29.53 24.57 to 29.16 27.00 to 23.53 23.73 to 26.63 Grand totals -- 30.48 to 30.42 32.97 to 32.99 33.57 to no change 30.00 to 30.53 32.73 to 30.73

VOLUME II - SECTION 2

p 36 -- para 2.1.5.3(2)	Change Section 1, para 1.1.5.3.1 to para 1.1.5.3.
p 38 -- para 2.2.2	Change the following: Mand Value = 28.34 to 29.09 Std. Dev. = 5.48 to 6.41 34.99 -- no change 32.05 -- 34.05 25.20 -- no change 21.12 -- to 22.12
p 39 -- Figure 2.2.1(a)	Under RIO, the (*) signifies that a limited number of antenna elements in the BCA are required -- less than for either CHETSA or Barrel Stuffing
p 40 -- Figure 2.2.1(b)	Under R5, change .2 to 2 Under R8, change .2 to 2 Subtotals -- 28.99 to 28.82 22.20 to 21.14 18.12 to 18.77 26.05 to 28.44 Grand totals -- 34.99 -- no change 25.20 -- no change 21.12 to 22.12 32.05 to 34.05

VOLUME II -- SECTION 3, PART 1

p 48 -- para 3.1.1.5.1 — ID $\geq$ 4 inches

p 49 -- para 3.1.1.5.2(2)&(3) — Rigid, leakproof joints required at > 1500 Psid for Pressure Hull Penetration Point and Seal and Valves?

NUSC comment - not necessary. CID must request clarification of this comment.

— para 3.1.1.5.3 — Large dia. impacts on BCA buckling?

There is a direct relationship between conduit bore to BCA diameter which determines susceptibility to buckling.

p 59 -- para 3.1.2.2(h) — Change the following:

20 knots to 15 knots
3535#f to 2200#f
1.492 to 1.874

p 60 Figure 3.1.2.2(f) — Change the following:

HP = 1.481X (μ=.25)	HP = 1.874X (μ-.40)	HP = 2.372X (μ-.55)
26.92	34.07	43.12
40.39	51.10	64.68
53.85	68.14	86.25
35.90	45.43	57.50
53.85	68.14	86.25
71.80	90.85	114.99
44.87	56.78	71.87
67.31	85.17	107.81
89.75	113.56	143.74
53.85	68.14	86.25
80.77	102.21	129.37
107.70	136.28	172.49

p 61 -- Figure 3.1.2.2(g) — Disregard figure, use new data above.

p 62 -- Figure 3.1.2.2(h) — Change the following:

1.492X to 1.874X
5000#f to 4.25#f & 30.30 to 25.00
48.6 HP reqd. to 50.37 HP reqd.
20 knots to 15 knots
1739#f to 1925#f
553#f to 613#f/linear foot

p 63 -- para 3.1.2.2(j)	Change the following:
	1739#f to 1925#f 10.54 HP to 11.67 HP 10.54 HP to 11.67 HP 446.9 BTUs/Min to 494.6 BTUs/Min
p 64 -- para 3.1.2.2(j) cont.	Change the following:
	63.8 BTUs/Min to 70.73 BTUs/Min 5.1°F to 5.5°F
	Figure Q_{gen} 446.9 to 494.6
p 65 -- para 3.1.2.2(j) cont.	Change the following:
	383.2 BTUs/Min to 423.9 BTUs/Min 1231°F/Min to 1362.2°F/Min 446.9 BTUs/Min to 494.6 BTUs/Min 10.30°F to 11.40°F 10.30°F to 11.40°F <10.30°F to <11.40°F

VOLUME II -- SECTION 3, PART 2

p 69 -- para 3.2.1.2	---6.5 inches? Explanation -- only if the valve(s) under discussion are inboard of the dynamic seal. Only the Failsafe Shutoff Valve (FSV) must achieve this requirement. However, it is desirable that both the Hull Valve (HV) and FSV be similar/or identical, with the FSV being the "second" valve required for SUBSAFE conditions.
p 73 -- para 3.2.1.5.3(1)	Add ". . . equal to that of the pressure only as far as the Hull Insert."

VOLUME II - SECTION 3, PART 3

p 85 -- para 3.3.1.1	Leakage values too high?
	Explanation — an engineering design assumption only. Testing is essential in order to verify any values.
— para 3.3.1.2	Delete the words "without" and "and."
p 86 -- para 3.3.1.2	Change 8.8#/in.^{2} to 4.08#/in.^{2}
p 90 -- para 3.3.1.5.3	Conduit/Guide Tube?
	Explanation — There will be Conduit/Guide Tube both inboard and outboard of the Pressure Hull insert. Perhaps a redefinition for the inboard portion could be to call it all part of the staging tube subsystem.
p 92 -- para 3.3.2.2	Change the following:
	Mean Value = 28.04 to 29.18 Std. Dev. = 1.60 to 2.72 30.74 — 33.08 28.31 -- 28.64 27.33 — 28.23 25.78 -- 26.79
p 93 -- Figure 3.3.2(a)	Change the following:
	R9, 11, & 14, add arrows between #s.
p 94 -- Figure 3.3.2(b)	Change the following:
	R3 -- .33 to .66; .66 to 2, 1 to 2, & .33 to 1.33 R6 -- under fixed -2 Posn., Split -- change .66 to 2
	Subtotals:
	22.31 to 22.67 22.78 to 20.77 27.74 to 24.33 21.33 to 22.65
	Grand totals:
	28.31 to 28.64 25.78 to 26.79 30.74 to 33.08 27.33 to 28.23

VOLUME II -- SECTION 4

p 101 -- Figure 4.1.4.1	Does not show method to prevent rotation of the articulated bellmouth?
	Explanation: Rotational forces are very low, with pivoting forces far greater. If rotation cannot be prevented, the contour geometry would have to be uniform. Further definition will be required, although this is not foreseen as a high risk item.
p 104 -- para 4.2.2(1)i	Delete ... and a load of 6205.2#f.
-- para 4.2.2(1)iii	Change the following:
	.530 to .64^{o}/3^{o} x 2 in. + 2 in. or (.353 linear inches to 2.427 linear inches) .088 in.^{2} to .608 in^2 785.3 psi to 114.33 psi 5.20 psi to 14.72 psi
p 105 -- para 4.2.2(2)ii	Change the following:
	Delete ... X2
	Add +2 in after 1.06^{o}/3^{o} x 2" Change .707 to 2.707 and 378.7#f/linear ft to 98.85#f/linear ft

p 116 -- R20, Single Drum Capstan -- Confusing?

	Explanation -- comparison of various hydraulic vs electric drive options, i.e., 1 ea. Hagglund 3160 hyd. motor vs either 7 ea. PMI 3/2.5 or 4 ea. PMI 3/2.5 pressure compensated fluid-filled electric motors. An additional option would be a single 6/4.5 PMI pressure compensated electric motor.
p 121	Asterisk -- signifies reference to previous traction belt optimization
p 125	Laminar Fluid (6) Change +1 to +2
p 127	Laminar Fluid (3) 1000 psi (best)?
	Explanation -- This loading is absolutely uniform and is very similar to the pressure imposed due to ambient sea pressure.
p 128	Laminar Fluid -- (2 psi)?
	Explanation -- contribution of imposed shear loading due to fluid pressure required to generate a driving force.
p 129 -- R3, Clamp Traction	Change +AdB to +3AdB

p 133-R5	Change the following: 302 psi to 906 psi 3 ft to 1.5 ft for all references 100 psi to 302 psi The tradeoff chart figure 2.2.2(a) 8(b) must be changed to reflect this adjustment. The relative advantage does not change, nor does the results of the Tradeoff Analysis.
p 142 -- R7	Change 1.636 to .136 ft.
p 154 -- R1	Closed? Explanation — closed implies engaged about the cable periphery.
— R9,10,11&14	Change AQ to Q.
p 147 -- Inherent Reliability	(*)? Explanation — the bullet above should be an asterisk and the Severity Factor statement should be a footnote.

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Deploy/Retrieve/Storage System (DRSS)
Contract N00039-79-C-0329

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VOLUME II - COMPONENT DEFINITION AND TRADEOFF ANALYSIS

SUMMARY

VOLUME II - COMPONENT DEFINITION AND TRADEOFF ANALYSIS

SUMMARY

This volume has been prepared as part of the DRSS Final Report. This volume documents the analysis and optimization efforts performed at the component level, and provides the basis for analysis and optimization efforts performed at the system level in Vol. I.

This volume addresses the four key study areas:

Section 1 - Deploy/Retrieve Mechanism

Section 2 - Cable Storage

Section 3 - Cable Guide

Section 4 - Tow/Exit Point

The Antenna Assembly electrical/mechanical performance characteristics and interface requirements are defined where pertinent to the analysis in each section.

Technical objectives of the study efforts are (1) to support the conceptual design and perform tradeoff analysis of a DRSS which shall payout, retrieve and stow present and future buoyant cable antenna assemblies while the submarine is submerged; (2) meet specified Requirements and Goals per Statement of Work (SOW) paragraphs 3.2.2 and 3.2.3; (3) ascertain ranking of component concept configurations via specified tradeoff priorities per SOW paragraph 3.3; and (4) implement Design to Cost considerations per paragraph 3.4.

The requirements for developing a DRSS concept and addressing the technical objectives were:

1. The system shall be positive self-sealing under all conditions at all external interfaces to maximum depth of the submarine.

2. The system shall be capable of shearing the antenna assembly and completely sealing the pressure hull boundary.

3. The structureborne and airborne noise (within one (1) foot of any portion of the DRSS), at all payout/retrieval speeds shall not exceed the levels specified in NUSC drawings SKA-55250 and SKA-55251 respectively.

4. The antenna assembly including all antenna elements and in-line devices shall be deployed and totally retrieved while the submarine is submerged at all depths.

5. The system shall not exert excessive compressive, torsional bending or tensile loading within the DRSS.

6. Typically, the system shall be installed within the confines of the existing superstructure of SSN 637 and 688 submarine and compatible with SSBN submarines.

7. The total volume of the DRSS shall not exceed 85 cubic feet.

8. The deploy, retrieve mechanism and storage portion of the DRSS shall be accessible for repair/maintenance while the submarine is submerged.

9. The in-line connectors, electronic and housing connectors shall be similar to that shown on NUSC drawing D-02387-001, D-02386-001 and D-02378-001 but may vary in diameter according to the cable utilized. The maximum length shall not exceed 6 ft. in length and 1.0 inch in diameter. Minimum requirement length is 12 inches and 0.650 $\pm$ 0.025 inches in diameter.

10. The cable construction and materials shall be similar to buoyant cables specified in NUSC Specification NUSC-C-342/4141-279.

11. The antenna elements associated with the antenna assembly shall not exceed 6 ft. in length and 6 inches in diameter. Minimum requirement is 4 ft. long and 4 inches in diameter.

12. The antenna assembly length shall not exceed 5,000 ft. based on a nominal cable diameter of 0.650 inches. Minimum requirement is 3,000 ft. with a cable diameter of 0.650 inches.
13. The maximum static tensile loading at the tow point shall not exceed 10,000 lbs. Minimum requirement is 6,000 lbs.
14. The cable diameter shall be 0.650 to ± 0.020 inches in diameter.
15. The maximum payout/retrieval speed of the DRSS shall not be less than 200 fpm.
16. The DRSS shall be capable of sustaining a minimum dynamic loading of 3,000 lbs.
17. The cable deployed shall be measured and indicated to within ± 5 feet.
18. The DRSS system shall not require more than 2 persons with technical ratings to operate/control the deploy/retrieve and storage.
19. The total weight of the DRSS including foundations, controls, etc. shall not exceed 3500 lbs.
20. The maximum power available within the pressure hull or superstructure for DRSS utilization is assumed to be the following:

    Hydraulic - 3000 psi with max. flow rate of 30 gpm

    Electrical - 220/440 VAC-60 Hz with 300/150 amps Results of the studies made indicate the following:

The goals for developing the DRSS concept(s) and tradeoff analysis were:

1. A design goal of the DRSS is to be compatible with cable which can vary in diameter between 0.50 and 1.00 inches. The diameter would remain constant with ± 0.025 inches for relatively long lengths of cable. The specific gravity of the cable could be between 0.60 and 0.75 of 0/psi hydrostatic pressure for all cable diameters specified.
2. A design goal is to provide the DRSS with a capability to payout and retrieve cable at speeds not less than 400 fpm.

3. As a design goal, the maximum dynamic tensile loading the DRSS shall sustain is 6000 lbs. at maximum cable retrieval speeds.
4. A design goal of the DRSS is to measure the amount of cable paid out to within ± 1 foot.
5. A design goal of the DRSS system is operation/control of deploy/retrieve/storage by one person with a technician rating.

In developing the DRSS concept(s) the order of priorities for tradeoff studies was:

1. Performance based on achieving the maximum number of design goals.
2. Installation impact on available space and weight within the existing superstructure.
3. Per unit cost based on achieving the maximum number of design goals.

The goal of a moderate cost DRSS is an essential part of this program. The cost was considered when performing tradeoff analysis of the concept(s) including the individual subsystems. Cost goals were based on FY 79 dollars, assuming quantities (by year) shown in Table 1. The quantities shown were established for tradeoff analysis only, and do not indicate actual plans or intent for procurement of production units. The design to cost goals were:

DRSS Production Cost - $175K

Installation Cost - $200K

Table 1

	1985	1986	1987	1988
DRSS (SSN and SSBN)	10	30	30	50 - 70

Results of the studies made indicate the following:

1. a. It is conceptually feasible, at the component level, to meet <u>all</u> specified Requirements.

   b. Achievement of <u>all</u> design goals is also possible with the following qualifications:

   - Envelope and weight allocations will increase in order to meet the dynamic load goal for the Deploy/Retrieve Mechanism.

     This is due to the tractive length increase required to meet the increased dynamic load. Improved shear stress capability of the buoyant cable assembly (BCA) would eliminate this increase. Refer to Section 1 for a detailed discussion.

   - If both payout/retrieval speed and dynamic load capability are considered as mutual goals, the hydraulic power available will limit one or the other.

   - Structureborne/Airborne noise generation at design goal payout/retrieval speeds dictates stringent limitations on feasible component configurations for the Deploy/Retrieve Mechanism.

2. A statistically significant difference separates the relative ranking of component configurations analyzed for the Deploy/Retrieve Mechanism, Storage Assembly, and Dynamic Seal via a matrix tradeoff chart. The highest ranking components are integrated at the systems level to develop a recommended system concept configuration which can meet the technical objectives defined by the SOW. (Vol. I presents details of this analysis.)

INTRODUCTION

INTRODUCTION

This volume is the second of two submitted as a Final Report of the DRSS study effort. The four key study areas are: (1) Deploy/Retrieve Mechanism; (2) Cable Storage; (3) Cable Guide and (4) Tow/Exit Point.

The Deploy/Retrieve Mechanism study, Section 1, provides definition, configuration, characterization and evaluation criteria tradeoff analysis based upon the specified Requirements and Goals, and additional CID evaluation criteria as listed in the Tradeoff Summary Chart. Five separate and distinct approaches to development of Deploy/Retrieve Mechanisms are analyzed, rank established, and recommendations made.

The Cable Storage study, Section 2, provides an identical approach to that of the Deploy/Retrieve Mechanism, with four separate and distinct approaches developed. Characterization, analysis, relative ranking, and recommendations are similarly provided.

The Cable Guide study, Section 3, is broken down into three parts: (1) Conduit/Guide Tube characterization, analysis and recommendations; (2) a Valves discussion with recommendations; (3) a dynamic seals definition for four separate and distinct configurations, characterizations and tradeoff analysis employing evaluation criteria based upon the specified Requirements and Goals, and additional CID evaluation criteria. Ranking is established and recommendations made.

The Tow/Exit Point study, Section 4, provides definition, characterization, analysis, and a recommended configuration.

Design to Cost considerations have been established at the component level via a hardware cost and factored at the system level to generate a Unit Production Cost allocation for each of the System Concepts evaluated. Relative development costs and installation costs are addressed and integrated at the System Concept level.

Each study section provides the following information:

Introduction

- Definition
- Problem Areas
- Requirements
- Analytical Approach
- Candidates

The introduction to each of the studies specifically addresses those Requirements and Goals pertinent to the candidates addressed in each of the individual studies.

Discussion

- Analysis/Tradeoff Summary Chart(s) Explanation
- Ranking Summary
- Analysis of Results
- Recommendations

The discussion for each of the studies addresses the tradeoffs/analysis employed to generate the recommendations. Where required, matrix tradeoff charts are employed to support the discussion. These tradeoff charts are themselves supported by an evaluation criteria analysis (ECA) which provides a brief summary description of the methodology employed in generating the numerical assessment presented in the Tradeoff Chart. The ECA refers to supporting Appendices as the basis for all characterizations made.

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VOLUME II, SECTION 1, DEPLOY/RETRIEVE MECHANISM STUDY

SECTION 1

DEPLOY/RETRIEVE MECHANISM STUDY

1.1 INTRODUCTION

1.1.1 Definition

1.1.1.1 The Deploy/Retrieve Mechanism is a mechanical device for paying out and retrieving the antenna assembly while the submarine is submerged. The present buoyant cable antenna systems include either the AN/BRA-24 or the AN/BRA-18 antenna transfer assemblies. The AN/BRA-24A is identified in NAVSEA Technical Manual 0967-LP-301-2010, AN/BRA-24C in NAVSEA Technical Manual 0967-LP-608-5010 and the AN/BRA-18C in NAVSHIPS Technical Manual 0967-LP-325-8010.

1.1.1.2 The concept(s) shall develop a system/method for deploying and retrieving present and future antenna assemblies at maximum tow speed and cable lengths. The concept shall utilize power available onboard the submarine. The deploy/retrieval mechanism shall be compatible with all in-line components, cables and antenna assemblies.

1.1.2 Problem Areas

1.1.2.1 The present system has the following major problem areas; exerts excessive compressive, bending, torsional and tensile forces on in-line electronic, connectors and antenna assemblies developed for present and future antennas, restricts the development of future antennas and associated components, requires extensive effort for maintainability, requires a bend radius of 6" on in-line electronics and associated components; introduces excessive structureborne noise; requires excessive manpower/effort to deploy/retrieve antenna assemblies; and does not accurately determine amount of cable deployed.

1.1.2.2 From the above, we infer that the transfer mechanism has been responsible for existing buoyant cable antenna (BCA) handling system failures and antenna/cable damage.

Part of the problem appears to stem from the detail mechanism design. However, inherent in the concept of the AN/BRA-24 is the problem associated with bending the cable/antenna assembly connectors and amplifiers around a small diameter drum. In the DRSS system, the requirement to incorporate antenna elements from 4.0 to 6.0 inches in diameter will aggravate these problems.

The proposed DRSS system concepts described in paragraph 1.1.5, define mechanisms which can be automatically adapted to BCA diameter changes and can readily handle these longer, larger diameter sections without inflicting degrading bending stresses.

Since the present antenna/cable assembly is specified at 100 pounds shear/linear foot, any transfer mechanism or wiper type seal must be limited to less than this tension applied per foot of length in order to prevent damage to the antenna. This means that a capstan or traction device can only apply 100 pounds/ft pull. It is therefore possible to relate the length of antenna which must be subjected to retrieval tension to the retrieval ship's speed and retrieval rate. Figure 1.1.2.2(a) relates the traction length to ship's speeds for inhaul speeds of 200 FPM and 400 FPM. The values are obtained by adding inhaul speed to ship's speed, determining the equivalent drag from Figure 1.1.2.2(b), applying the multiplication factor for conduit bends derived in paragraph 3.1.1.2 and dividing by 100 pounds/ft.

The shear strength of 100 pounds/linear foot amounts to 8.33 pounds/inch. More than this loading could pull the jacket off of the antenna. Therefore, traction treads or wiper seals of rubber with coefficient of friction 1.0 cannot press against the jacket with more than 8.8 PSI when the antenna is being moved.

Based on 100 lbs/foot cable shear strength and the requirement that the transfer mechanism be capable of pulling with 3000 pound dynamic force on the antenna, the traction length must be $\frac{3000}{100} = 30$ feet. This is equivalent to 2.4 wraps around a 4 foot diameter capstan. This conflict of the dynamic force requirement and the available space

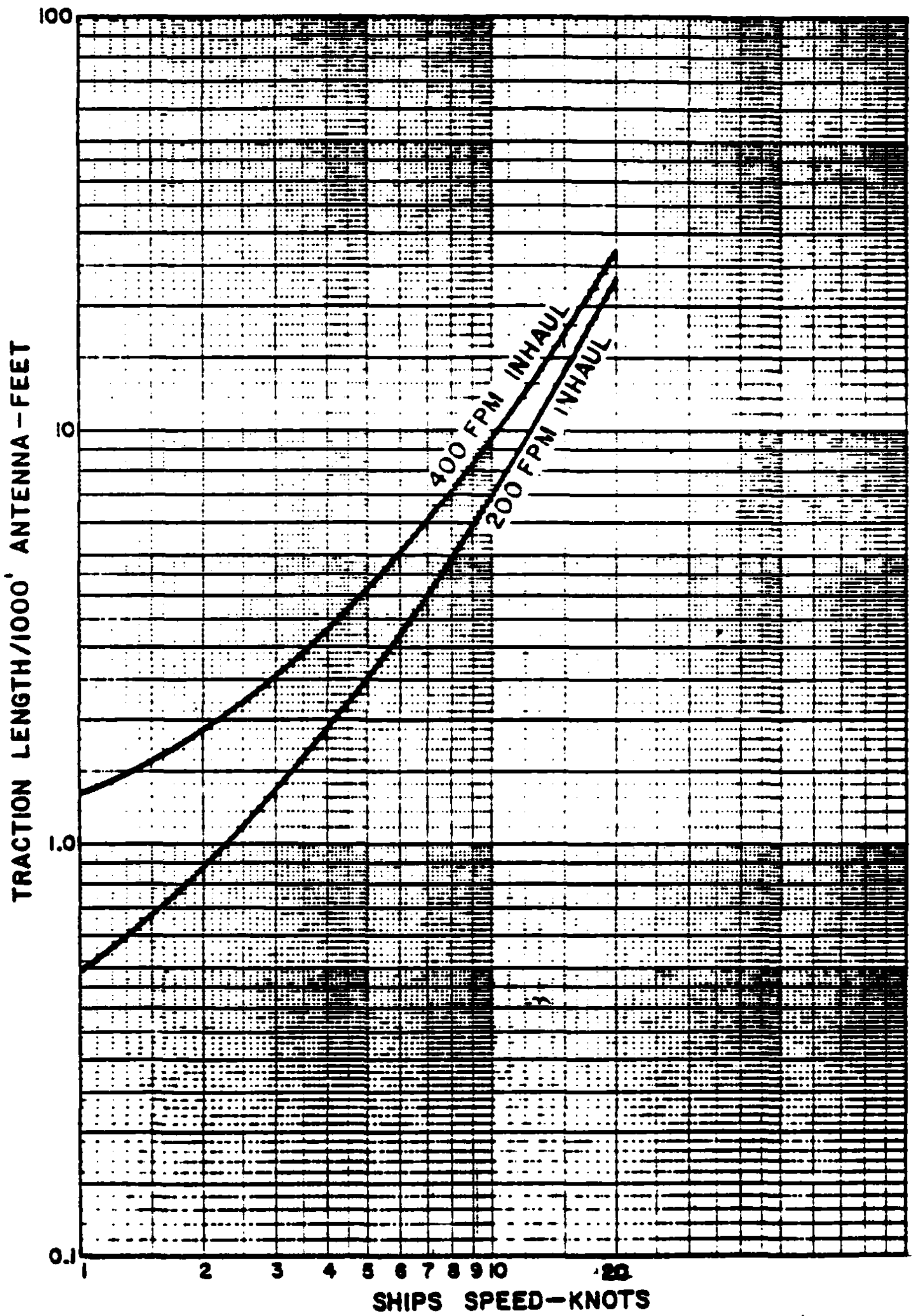

Figure 1.1.2.2(a). Required Traction Length for 1.0 Inch Diameter Cable With 100 lb/ft Shear Strength

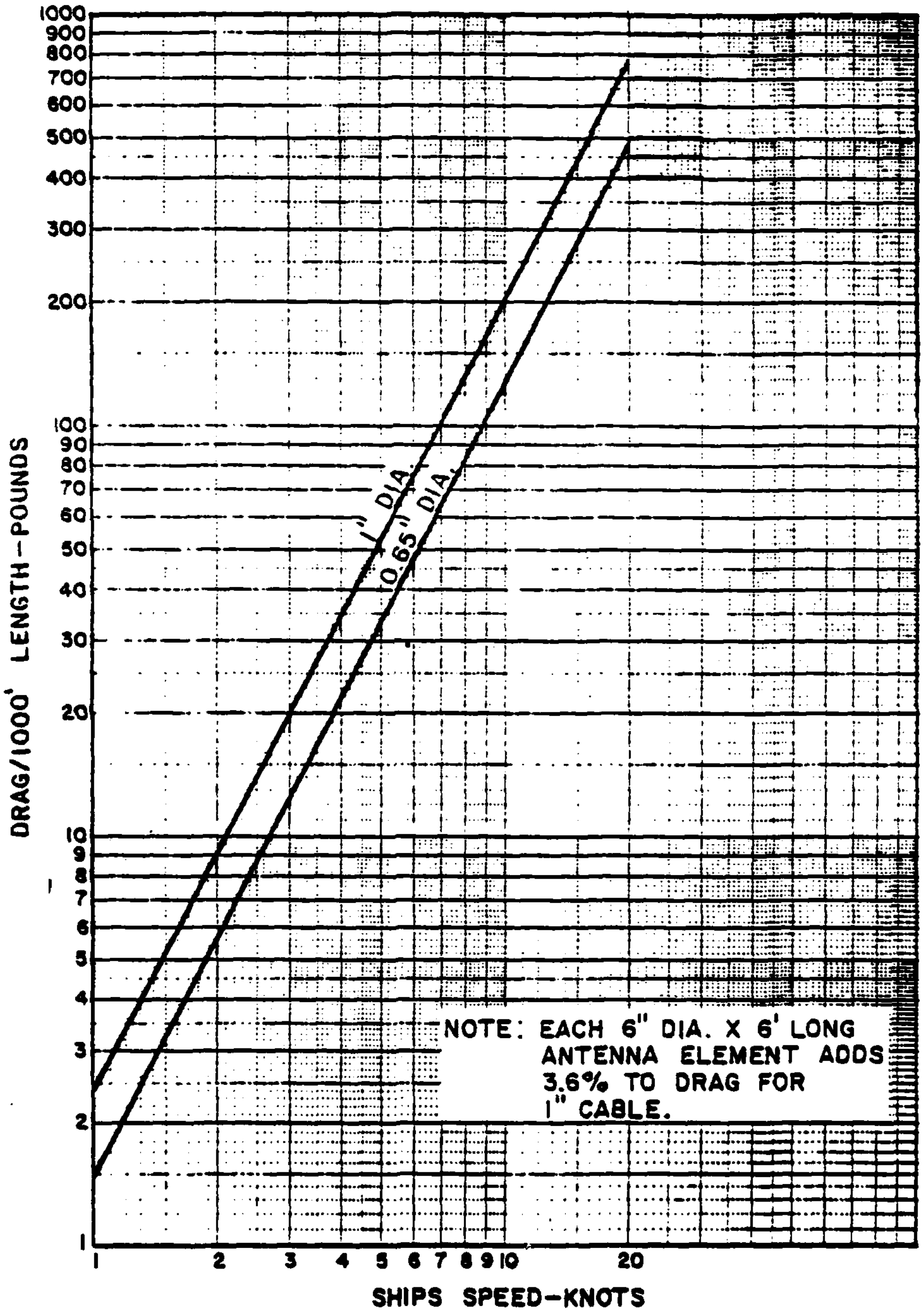

Figure 1.1.2.2(b). Drag Versus Speed in Knots for Various Antenna Configurations

for the transfer mechanism could be mitigated by an improvement in the antenna/cable shear strength. For example, if the shear strength is increased by a factor of 7 to 700 lbs/foot, the required traction length drops to 4.3 feet for a linear traction device.

Relating the above to ship speed, Figure 1.1.2.2(a) shows that for a ship speed of 5 knots, a cable retrieval speed of 200 feet per minute, and a 3000 long antenna, the required traction length is about 7.5 feet.

The above analysis indicates that the traction length will be a major factor in transfer mechanism tradeoffs. The capstan concept provides the greatest traction length in a small convenient geometrical package, however, bending stresses induced on the antenna/cable assembly components are a serious disadvantage for bend radii less than two feet.

A tractor tread concept similar to the BRA-18 transfer assembly is most advantageous from an antenna/cable handling standpoint but suffers from the greater length necessary to achieve the required retrieval force.

The details of this tradeoff are generated in the discussion. The important requirements for the transfer mechanism are it:

a. Must automatically adapt to accommodate BCA diameters from 0.5 to 6.0 inches.

b. Must have sufficient traction length to apply 3000 lbs. of retrieval force to the cable/antenna without damage.

c. Must have sufficiently gentle bend radius to handle the antenna/cable components without applying damaging bending and torsional forces.

1.1.3 Requirements

1.1.3.1 The allocated Requirements and Goals to the Deploy/Retrieve Mechanism are as shown in Figure 1.1.3.1.1. Additional CID evaluation criteria which were employed are:

a. No. of Components - determine relative complexity.

b. Inherent Reliability - determine a characteristic MTBF.

c. Development Cost - determine relative budgetary cost estimate to produce a working prototype including drawings.

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DRSS SOW REQUIREMENTS/GOALS
ALLOCATION TO COMPONENT LEVEL

COMPONENT	REQUIREMENTS	GOALS
• TOW/EXIT POINT	4, 5, 6, 10, 11, 13, 14, 15, 16	1,2,3
• CABLE GUIDE -		
- CONDUIT	4, 5, 6, 9, 10, 11, 13, 15, 16	
- SEALS & VALVES	1, 2, 3, 4, 5, 6, 10, 11, 14, 18	1
- CABLE/ANTENNA ELEMENT SHEAR DEVICE	1, 2, 4, 6, 9, 10, 11, 14, 20	
• DEPLOY/RETRIEVE MECHANISM	3, 4, 5, 6, 8, 9, 10, 11, 13, 14, 15, 16, 18, 20	1,2,3,5
• STORAGE ASSEMBLY	1, 3, 5, 6, 8, 9, 10, 11, 12, 13, 15, 16, 20	1,2,3,5
• SENSORS	1, 4, 5, 6, 9, 10, 11, 12, 14, 15, 16, 17	1,2,3,4
• CONTROLS	3, 6, 15, 17, 18, 20	2,3,4,5
• POWER SOURCE	3, 6, 8, 15, 16, 20	2,3
• ANTENNA/RF INTERFACE	1, 2, 4, 5, 9, 10, 11, 12, 13, 14, 15, 16, 17	2,3,4

NOTE: (1) REQUIREMENTS #7 & 19 ARE APPLICABLE TO ALL OF THE ABOVE.

Figure 1.1.3.1.1. DRSS SOW Requirements/Goals Allocation to Component Level

d. Cable Contact Efficiency - characterized determination of cable handling method, and the consequent potential degree of impact on the cable structure geometry.

e. Friction Dependence - evaluation of the susceptibility of performance degradation based on environmental friction characteristics variability vs a minimum friction required by the particular mechanism to transmit energy into the cable assembly system.

f. Fatigue/Wear Impact - characterized determination of the cable handling method, and the consequent impact on cable structure failure.

g. Producibility - relative estimate of degree of difficulty in fabrication/assembly and qualification test of the particular mechanism analyzed.

1.1.3.2 All allocated Requirements/Goals and CID evaluation criteria are employed to determine the relative ranking of the component configurations analyzed, in Tradeoff Summary Chart(s), Figures 1.2.1(a) and 1.2.1(b).

1.1.4 Analytical Approach

1.1.4.1 Each candidate component configuration is analyzed/charactgerized, to the extent necessary, to support the generation of numerical values which can be employed in the tradeoff summary charts for assessment of the degree to which each evaluation criteria can be met. Separate Appendices A through E provide the basis for all characterizations made for the particular component analyzed. An evaluation criteria analysis, Section 5, provides a brief summary description of the methodology employed in generating the numerical assessment values presented in the Tradeoff Summary Chart Figure 1.2.1(a). Data presented in this chart is normalized and weighted in order to establish the relative ranking of each of the candidates, and is shown in Tradeoff Summary Chart Figure 1.2.1(b). A ranking summary, analysis of results, and recommendations are made in paragraphs 1.2.2, 1.2.3, and 1.2.4 respectively, based upon the data presented in Figure 1.2.1(b).

1.1.5 Candidates

1.1.5.1 A review of the present BRA-24 and BRA-18 buoyant cable antenna handling system capabilities and problem areas, analysis of the SOW Requirements and Goals, and comparison to existing technology and hardware adaptable to application as a Deploy/Retrieve Mechanism, has resulted in the selection of five possible candidates. They are as follows:

Candidate	Closest Analogy/ Similarity	Refer to Figure	Refer to Analysis
• Linear Traction	BRA-18	Fig. 1.1.5.1(a)	Appendix A
• Clamp Traction	Pultrusion, Mech.	Fig. 1.1.5.1(b)	Appendix B
• Single Drum Capstan	BRA-24 & CHETSA	Fig. 1.1.5.1(c)	Appendix C
• Laminar Fluid	Pultrusion, Fluidic	Fig. 1.1.5.1(d)	Appendix D
• Direct Windup	AN/SQR-19	Fig. 1.1.5.1(e)	Appendix E

1.1.5.2 Each candidate operates on a different principle, with characteristics unique to the cable handling technique employed. The configurations depicted are idealized concepts which establish the basis for analytical characterizations in the respective Appendices A through E. Each Appendix includes a concept configuration layout, description, operating explanation, considerations made in the analysis, and where required, references to Appendices F through I which support the study effort characterizations.

1.1.5.3 The Deploy/Retrieve Mechanism interfaces with the following:

- Valves and Seals
- Storage Assembly
- Sensors
- Controls
- Conduit/Guide Tube
- Power Source

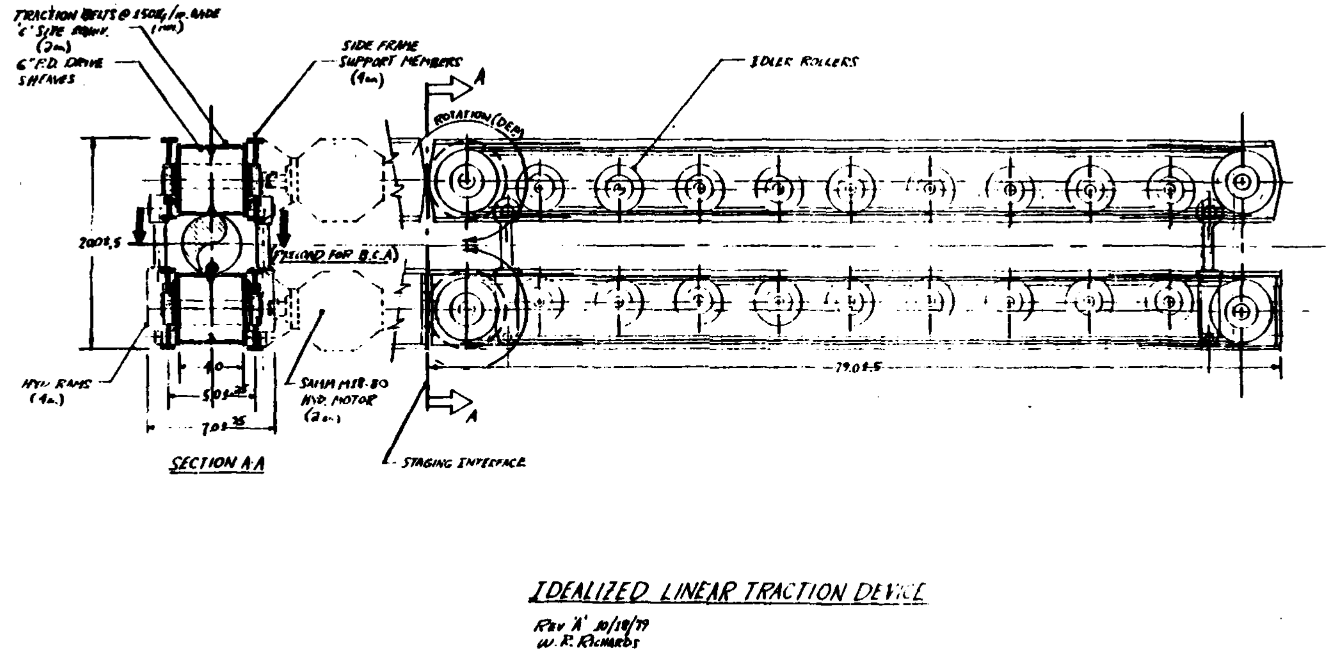


Figure 1.1.5.1(a). Idealized Linear Traction Device

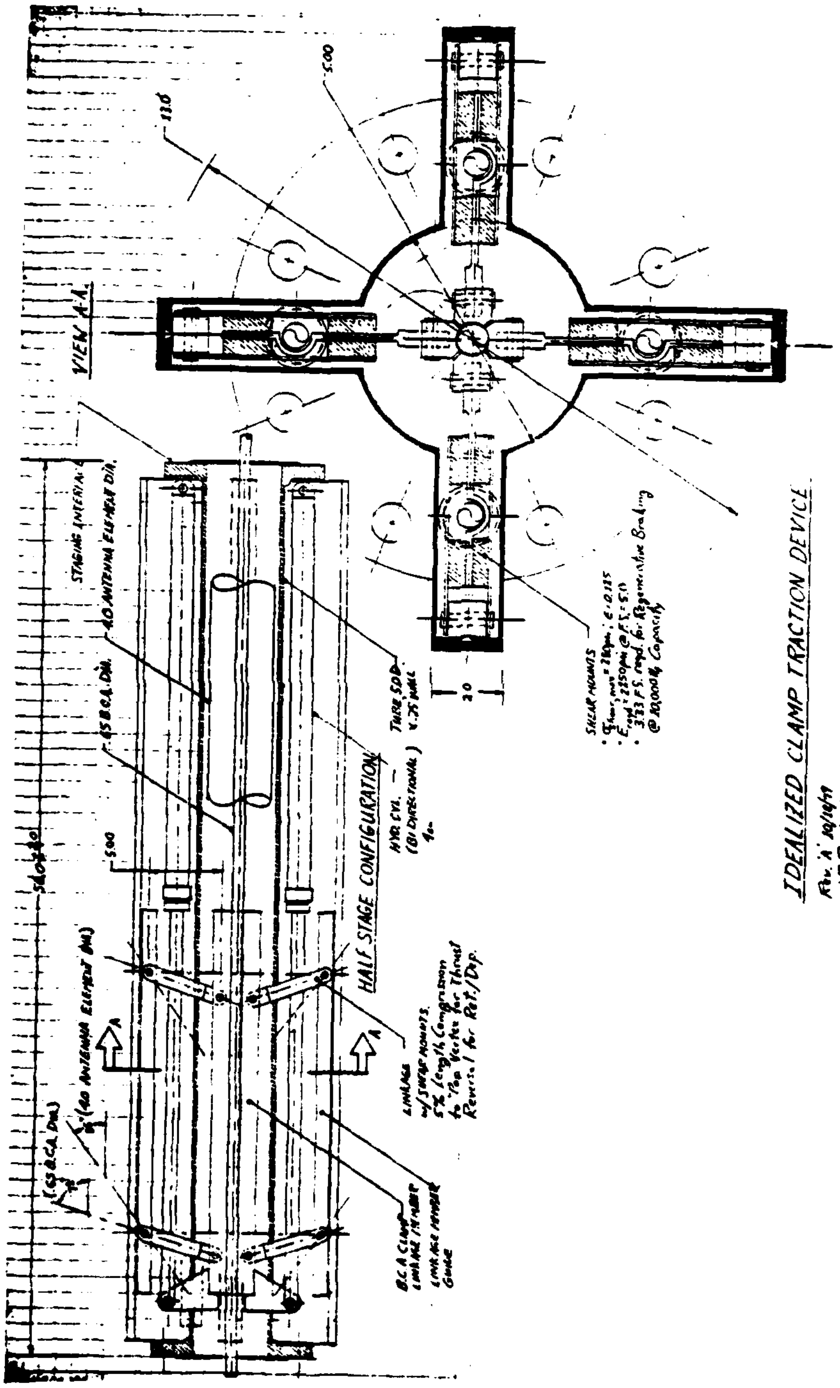


Figure 1.1.5.1(b). Idealized Clamp Traction Device

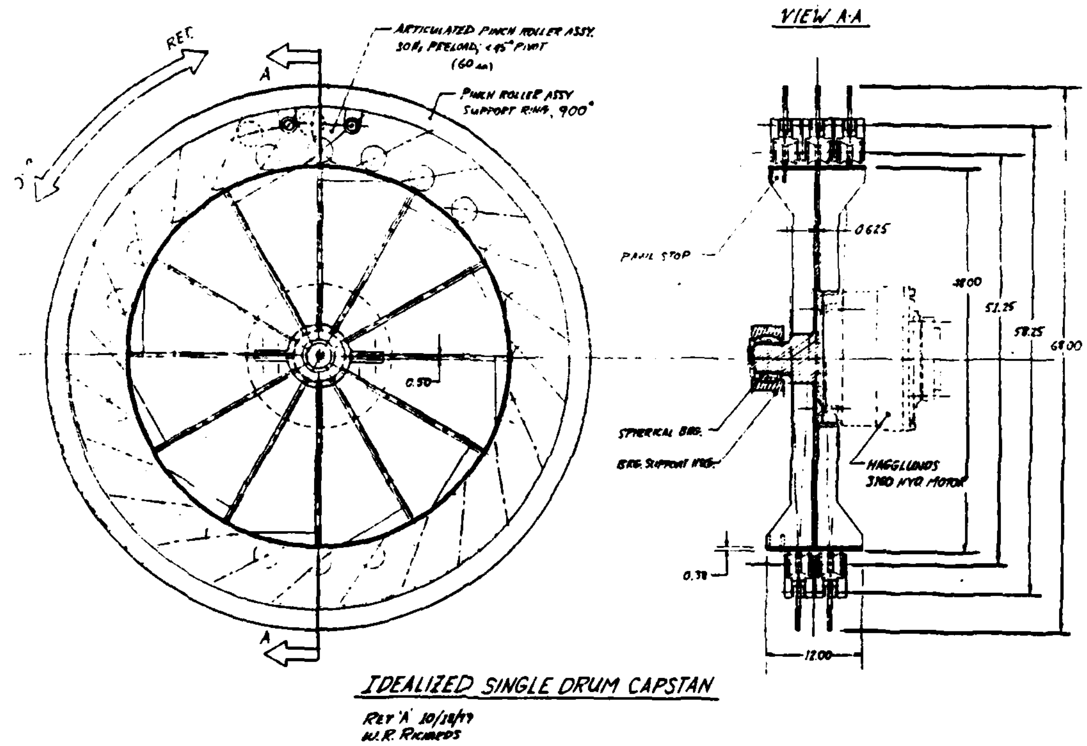


Figure 1.1.5.1(c). Idealized Single Drum Capstan

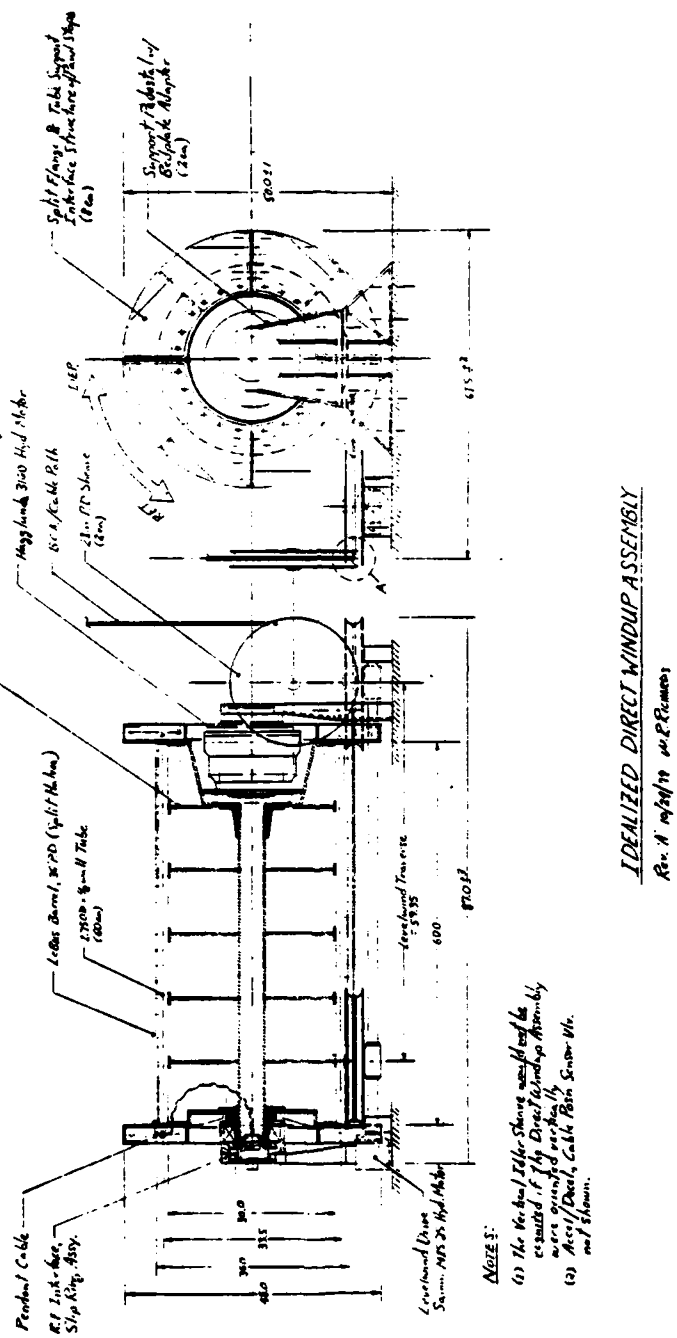
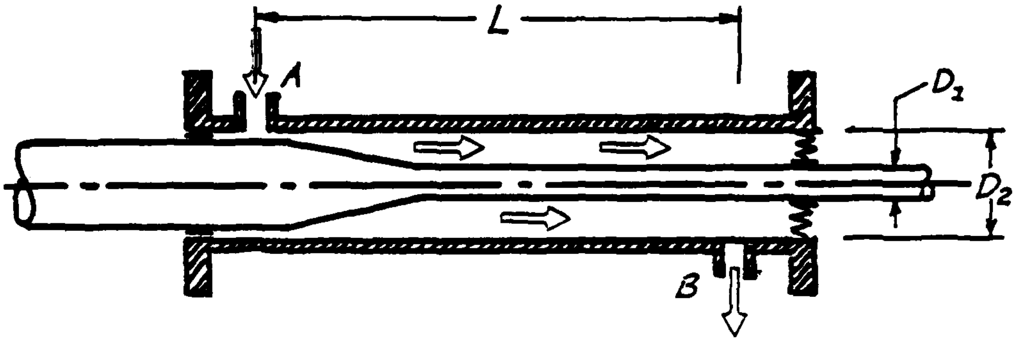


Figure 1.1.5.1(e). Idealized Direct Windup Assembly



- $\text{DRAG, } \#_f/\text{FT} = \dfrac{C_D \rho \, Vel^2}{2 g_c} A_{CABLE}/\text{LINEAR FT.}$

- $\Delta P, \ \#_f/\text{FT}^2 = \dfrac{2.15 \times 10^{-4} \times f \times \rho \times L \times Q^2}{d_{HYD}^5}$

- $d_{HYD} = D_2 - D_1$

- FLUID VISCOSITY $\geq$ 10,000 cs

Figure 1.1.5.1(d). Idealized Laminar Fluid Drive

Interface Requirements Discussion

(1) Valves and Seals:

Valves — Fail Safe Static Seal and Manual Static Seal

Due to the valve bore clearance required for 4" OD Antenna Elements w/.65 Dia. cable, the unsupported cable length susceptible to buckling prior to insertion into the dynamic seal assembly equals the cable path length from the last point of contact of the Deploy/Retrieve Mechanism to the Fail Safe Static Seal Valve plus bore path lengths of the two valves.

Seals — Dynamic Cable Seal Assembly

Pushing of the cable end through the seal will require capability to overcome a 60→200#f cable buckling force generated against the cable end by seawater ambient pressures from 0→600 psid operating conditions.

(2) Storage Assembly: The cable assembly must be capable of being completely removed from the Deploy/Retrieve Mechanism and being stored on the Storage Assembly.

The cable assembly be must under tension at all times for Deploy/Retrieve operation.

(3) Sensors:

Cable Scope — Employ RPMs count to achieve high accuracy, assuming zero slippage.

Speed Control — Employ pressure compensated, directional, servo flow control valving w/meter out flow regulation for single drive applications; and for multiple stage synchronization employ manifold assembly similar to

HPIs MCV-ISO System for independent simultaneous operation for up to 10 separate drive assemblies.

The PMI solid state brushless Torque Ring motor will require Hall Effect position sensors and/or encoders for input current gating.

(4) Controls:

<u>If Hydraulic</u> Subplate Manifold Assembly required to interface control/status information for a Control/Indication Panel.

<u>If Electric</u> A servo-controller w/DC Power Supply is required to interface to (1) Solid State Drive and (a) to a Control/Indication Panel.

(5) Conduit/Guide Tube: Assure that cable containment is maintained during deployment from the Deploy/Retrieve Mechanism discharge point to the first inline valve or seal assembly.

(6) Power Source: Hydraulic or Electric, refer to (3) above for speed control discussion. Refer to Section 3, Part 1 for discussion on imposed loads/hydraulic power supply adequacy. The selected configurations dictate allowable approach to power source selection.

1.1.5.4 A Pros and Cons Summary for each candidate configuration is presented in Figure 1.1.5.4.

Mechanism	Pro	Con
• Linear Traction Figure 1.1.5.1(a)	• Highly adaptable to varying cable diameters	• Speed Synchronization between Stages (5) required
	• Long and slender - can facilitate installation compatibility	• Low inherent reliability
	• "Zero" bending imposed on the buoyant cable antenna assembly	• No static load holding capability, i.e., must lock the Storage Assembly
		• Structureborne noise generation @ >200 FPM is a <u>serious problem</u>
		• Two-point "Squeeze" may deform cable geometry — impact on seal performance
		• Maintenance is difficult
• Clamp Traction Figure 1.1.5.1(b)	• Four-point (circumferential) loading of the B.C.A.	• Speed synchronization between stages (8) required
	• $10{,}000\#_f$ static (regenerative) holding capacity	• Low inherent reliability
	• High adaptable to varying cable diameters	• Structureborne noise generation @ >200 FPM is a <u>serious problem</u>
	• Long and slender - can facilitate installation compatibility	• Very serious cable buckling limitation as a function of a 2-ft stroke disp'l prior to seal passage
	• "Zero" bending imposed on the B.C.A.	• Maintenance is difficult
• Single Drum Capstan Figure 1.1.5.1(c)	• Very small package envelope requirement	• Requires -60 - articulated Pinch Roller Assemblies
	• High reliability	• Imposes bending on the B.C.A. — (approx 1/4th that of the BRA-24 system)
	• $10{,}000\#_f$ static holding capacity	• One-point loading exacerbates shear stress loading capability
	• Very low structureborne noise generation	
	• Adaptable to varying cable diameters	

Figure 1.1.5.4. Pros and Cons Summary Vol. II, Section 1 Deploy/Retrieve Mechanism

Mechanism	Pro	Con
• Laminar Fluid Figure 1.1.5.1(d)	• Extremely small package envelope requirement	• Very long (>60 ft) to achieve $3000\#_f$ dynamic load capability
	• Very high potential reliability	• Unproven concept
	• Extremely low potential structureborne noise generation << spec.	• 200 FPM capability probable limit
		• No static holding capability
	• Ideal cable handling technique	• Cable buckling characteristics indeterminate at this time
	• Potential to eliminate dynamic seals	• Requires a separate fluid recirculation system
• Direct Windup Figure 1.1.5.1(e)	• Good reliability	• Exceeds envelope requirement
	• Low structureborne noise generation	• Limits Antenna Element placement
	• Simple/proven concept	• Imposes bending on the B.C.A. -- (approx 1/3th that of the BRA-24 systems)
		• High cable loading under static conditions @ $>6000\#_f$
		• One-point loading
		• Requires levelwind
		• High impact on installation compatibility

Figure 1.1.5.4. Pros and Cons Summary Vol. II, Section 1 Deploy/Retrieve Mechanism (Cont'd)

1.2 DISCUSSION

1.2.1 Tradeoff Summary Chart(s) Figure 1.2.1(a) and 1.2.1(b) Explanation

The first Chart Figure 1.2.1(a) depicts the values derived in the evaluation criteria analysis. The second Chart Figure 1.2.1(b) depicts the final numerical summary, with values generated as follows:

(a) Select optimum value in each of the successive columns.

(b) Normalize all other values in that column against the optimum value.

(c) Apply the appropriate weighting factor, i.e., CID evaluation criteria @ Base Requirements @ 2X Base; and Goal @ 3X Base.

(d) Sum the horizontal rows to generate the intermediate Subtotal and the final Grand Total.

1.2.2 Ranking Summary

(a) Mean Value = 31.95; Standard Deviation = 1.60

(b) Ranking according to highest value - *with significant difference equal to 1* Std. Deviation from the maximum Ranking Values:

Single Drum Capstan	-	1st @ 33.57
Traction Clamp	-	1st @ 32.97
Direct Windup	-	1st @ 32.73
Traction Belt	-	2nd @ 30.48
Laminar Fluid	-	3rd @ 30.00

1.2.3 Analysis of Results

As can be seen from the ranking summary, a statistical tie for primary consideration exists. However, severe operational limitations for both the Traction Clamp and the Direct Windup Mechanism should be highlighted.

(a) Traction Clamp

- Low inherent reliability
- "High" structureborne noise

Allocated Evaluation Criteria		Traction Belt	Traction Clamp	Sgl. Drum Capstan	Laminar Fluid	Direct Windup
		Deploy/Retrieve Configurations				
SOW Requirements						
R3	Airborne Noise/Structureborne Noise	X	X	X	X	X
R5	Imposed Shear Stress/Tensile Stress	4.08/9047	2.45/9047	7.35/9047	2.04/9047	7.35/9049
R6	Installation Compatibility	X	X	X	X	X
R7	Envelope < 85 ft^3	32.02	34.30	25.21	9.90	86.54
R8	Maintainability/Accessibility	4	4	5	7	5
R9&14	In-line Connectors & Cable Size					
R10	Cable Construction & Materials	.65→4.0	.65→4.0	.65→4.0	.65 → 4.0	.65 → 4.0
R11	Antenna Elements Size > 4 in. x 4 ft					
R13	Static Load Capability > $6000\#_f$	-	10,000	10,000	-	10,000
R15	FPM Compability to 200	X	X	X	X	X
R16	Dynamic Load Capability to $3000\#_f$	X	X	X	X	X
R19	Weight < $3500\#_f$	1590	1907	2300	1631	2896
R20	Maximum HP Required	21.05	21.05	21.05	72.02	21.05
R20	Power Source Required	Hyd.	Hyd.	Hyd./Elec.	Hyd./Elec.	Hyd./Elec.
SOW Goals						
G1	Variable Cable Dia., 50 → 1.00 in.	X	X	X	X	X
G2	FPM Capability to 400	X*	X*	X	-	X
G3	Dyn. Load Capability to $6000\#_f$	X*,** ***	X*	X** ***	-	X** ***
	SUBTOTAL					
CID Evaluation Criteria						
-	No. of Components	390	664	74	4	61
-	Inherent Reliability $, MTBF	94	72	768	886	306
-	Development Cost, X 1000	180	202.3	1362	76.0	172.6
-	Cable Contact Efficiency	2	3	1	3	1
-	μ Dependence	.5	.33	.19	.002	.19
-	Fatigue/Wear Impact	3	3	1	3	1
-	Producibility	2.5	3	2	1	1.5
	GRAND TOTAL					

Figure 1.2.1(a). Deploy/Retrieve Mechanism Tradeoff Summary Chart

Code	Allocated Evaluation Criteria	Traction Belt	Traction Clamp	Sgl. Drum Capstan	Laminar Fluid	Direct Windup
		Deploy/Retrieve Configurations				
SOW Requirements						
R3	Airborne Noise/Structureborne Noise	1.5	1.5	2	2	2
R5	Imposed Shear Stress/Tensile Stress	1	1.67	0.55	2	0.55
R6	Installation Compatibility	2	2	2	2	2
R7	Envelope < 85 Ft^3	.62	.56	.79	2	.26
R8	Maintainability/Accessibility	1.14	1.14	1.44	2	1.72
R9&14	In-line Connectors & Cable Size					
R10	Cable Construction & Materials	2	2	2	2	2
R11	Antenna Elements Size > 4 in. x 4 ft					
R13	Static Load Capability > $6000\#_f$	-	2	2	-	2
R15	FPM Capability to 200	2	2	2	2	2
R16	Dynamic Load Capability to $3000\#_f$	2	2	2	2	2
R19	Weight < $3500\#_f$	2	1.66	1.38	1.95	1.10
R20	Maximum HP Required	2	2	2	.58	2
R20	Power Source Required	2	2	2	2	2
SOW Goals						
G1	Variable Cable Dia., .50 → 1.00 in.	3	3	3	3	3
G2	FPM Capability to 400	3*	3	3	-	3
G3	Dyn. Load Capability to $6000\#_f$	3*	3*	3**,***	-	3***
	SUBTOTAL	21.48	23.79	24.57	27.00	23.73
CID Evaluation Criteria						
-	No. of Components	.25	.1	.82	1	1
-	Inherent Reliability, MTBF	.11	.08	.87	1	.34
-	Development Cost, X $1000	.42	.38	.56	1	.44
-	Cable Contact Efficiency	.60	1	.33	1	.33
-	μ Dependence	.38	.57	1	1	1
-	Fatigue/Wear Impact	1	1	.33	1	.33
-	Producibility	.4	.33	.5	1	.66
	GRAND TOTAL	30.48	32.97	33.57	30.00	32.73

Figure 1.2.1(b). Deploy/Retrieve Mechanism Tradeoff Summary Chart

- Restrictive maintainability
- High degree of drive synchronization/coordination required

(b) Direct Windup

- Low inherent reliability (due to requirement for an additional deployment aid mechanism)
- Antenna Element placement restrictions
- Exceeds envelope restrictions

1.2.4 Recommendations

1.2.4.1 Select the Single Drum Capstan as the primary candidate offering the best possibility of meeting the Requirements/Goals and having the least developmental risk.

The shear stress limitation of 100 pounds per linear foot is a major system driver. Major system gains can be achieved if better cables can be designed. The system improvements include a decrease in the number of pinch roller assemblies, weight and envelope reductions and increased reliability.

Control of cable buckling under the initial deployment conditions of $0 \rightarrow 200\#_f$ compression must be resolved through further study.

TABLE OF CONTENTS

VOLUME II, SECTION 2, CABLE STORAGE STUDY

SECTION 2

CABLE STORAGE STUDY

2.1 INTRODUCTION

2.1.1 Definition

2.1.1.1 The Cable Storage Assembly is located inboard, is used to store the complete antenna assembly when retrieved, and is the mechanical electrical inboard termination/mating point for the antenna assembly.

2.1.1.2 The concept(s) address a method for storage of any portion of the antenna assembly not deployed. The storage portion of the DRSS is also the inboard termination/connectivity of the antenna assembly to rf subsystems.

2.1.2 Problem Areas

Available space will ultimately determine the configuration of the storage assembly.

The RFP requirements and goals specify that the cable can be up to 5000 feet long and 0.65 inch in diameter or 5000 ft long 0.50 → 1.00 variable diameter with an undefined number of antenna elements up to 6 inches in diameter and 6 feet long spaced along the cable.

Given an unlimited space to mount the storage assembly, the geometrical configuration and design details could easily be optimized. Since space is at a premium in any backfit installation, the details of the storage assembly must be evolved through a series of trade-offs.

The preliminary system configuration(s) studies, derived without rigorous analysis of shipboard space limitations, provide the storage assembly requirements discussed below.

1) The assembly should be capable of storing the cable integrally connected to large diameter antenna elements while deploying or retrieving at 400 feet per minute.

2) The assembly should exert a controlled line tension on the cable/antenna elements in conjunction with the transfer mechanism so that the inertias are matched to avoid slack and snap loads.

3) The assembly may have to be capable of withstanding a static line load equal to T.B.D. times the breaking strength of the cable.

4) The assembly may have to have a locking mechanism to avoid accidental loosening of the cable/antenna assembly and to withstand the static towing load of 6000 lbs. tension.

5) The assembly must have a minimum bend radius so that no degradation of the cable/antenna assembly occurs during operation or long term storage.

6) Configuration/structural requirements should be addressed towards insertion of the assembly through the access trunk.

2.1.3 Requirements

2.1.3.1 The allocated Requirements and Goals to the Storage Assembly are as shown in Figure 2.1.3.1.1. Additional CID evaluation criteria which were employed are:

a. No. of Components - determines relative complexity

b. Inherent Reliability - determine a characteristic MTBF

c. Development Cost - determine relative budgetary cost estimate to produce a working prototype including drawings

d. Cable Contact Efficiency - characteristic determination of cable handline method and the consequent potential degree of impact on the cable structure geometry

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DRSS SOW REQUIREMENTS/GOALS
ALLOCATION TO COMPONENT LEVEL

COMPONENT	REQUIREMENTS	GOALS
• TOW/EXIT POINT	4, 5, 6, 10, 11, 13, 14, 15, 16	1,2,3
• CABLE GUIDE -		
- CONDUIT	4, 5, 6, 9, 10, 11, 13, 15, 16	
- SEALS & VALVES	1, 2, 3, 4, 5, 6, 10, 11, 14, 18	1
- CABLE/ANTENNA ELEMENT SHEAR DEVICE	1, 2, 4, 6, 9, 10, 11, 14, 20	
• DEPLOY/RETRIEVE MECHANISM	3, 4, 5, 6, 8, 9, 10, 11, 13, 14, 15, 16, 18, 20	1,2,3,5
• STORAGE ASSEMBLY	1, 3, 5, 6, 8, 9, 10, 11, 12, 13, 15, 16, 20	1,2,3,5
• SENSORS	1, 4, 5, 6, 9, 10, 11, 12, 14, 15, 16, 17	1,2,3,4
• CONTROLS	3, 6, 15, 17, 18, 20	2,3,4,5
• POWER SOURCE	3, 6, 8, 15, 16, 20	2,3
• ANTENNA/RF INTERFACE	1, 2, 4, 5, 9, 10, 11, 12, 13, 14, 15, 16, 17	2,3,4

NOTE: (1) REQUIREMENTS #7 & 19 ARE APPLICABLE TO ALL OF THE ABOVE.

Figure 2.1.3.1.1. DRSS SOW Requirements/Goals Allocation to Component Level

e. Friction Dependence - evaluation of the susceptibility of performance degradation based upon environmental friction characteristics variability vs a minimum μ required by the particular mechanism to transmit energy into the cable assembly system

f. Fatigue/Wear Impact - characteristic determination of the cable handling method, and the consquent impact on cable structure failure

g. Producibility - relative estimate of degree of difficulty in fabrication/assembly and qualification test of the particular mechanism analyzed

2.1.3.2 All allocated Requirements/Goals and CID evaluation criteria are employed to determine the relative ranking of the component configurations analyzed in Tradeoff Summary Chart(s), Figures 2.2.1(a) and 2.2.1(b).

2.1.4 Analytical Approach

2.1.4.1 Each candidate component configuration is analyzed/characterized, to the extent necessary, to support the generation of numerical values which can be employed in the tradeoff summary charts for assessment of the degree to which each evaluation criteria can be met. Separate Appendices (J through M) provide the basis for all characterizations made for the particular component analyzed. An evaluation criteria analysis, Section 5 provides a brief summary description of the methodology employed in generating the numerical assessment values presented in the Tradeoff Summary Chart Figure 2.2.1(a). Data presented in this chart is normalized and weighted in order to establish the relative ranking of each of the candidates, and is shown in Tradeoff Summary Chart Figure 1.2.1b. A ranking summary, analysis of results and recommendations are made in paragraphs 2.2.2, 2.2.3 and 2.2.4 respectively, based upon the data presented in Figure 2.2.1b.

2.1.5 Candidates

2.1.5.1 Review of the present BRA-24 and BRA-18 buoyant cable antenna handling system capabilities, and problem areas, analysis of the SOW Requirements and Goals, and comparison to existing technology/hardware adaptable to application as a Storage Assembly, has resulted in the selection of four possible candidates.

Candidate	Closest Analogy/ Similarity	Refer to Analysis
• CHETSA	CHETSA	Appendix J
• W/Levelwind	AN/SQR-19	Appendix K
• Pressure Proof Access Trunk	-	Appendix L
• Barrel Stuffing	-	Appendix M

2.1.5.2 The CHETSA concept configuration has a 36 in. OD barrel, narrow flange-to-flange spacing, and large OD flange which eliminates the need for a levelwind mechanism. Additionally, employing low tension storage, imposed cable wrapping forces due to shear, point contact, bending and tension are minimized.

The w/Levelwind Concept configuration permits a reduction of the flange OD, along with an increase in the flange-to-flange spacing. It also has a 36 in. OD barrel. The levelwind mechanism permits much higher storage tensions due to the uniformity of layer buildup and the consequent improved support arrangement for cable overwrap.

The Pressure Proof Access Trunk Concept (PPAT) configuration provides means for incorporation of both the Storage Assembly and the Deploy/Retrieve Mechanism into a pressure vessel, and is analyzed with respect to minimizing envelope and weight requirements. A unique Storage Assembly configuration is defined and discussed.

The Barrel Stuffing Concept configuration provides a method for zero tension storage and windup, with associated loss in packaging efficiency. It is intended for a free-flood environment either in the ballast tank area, or within the PPAT.

2.1.5.3 The Storage Assembly interfaces with the following:

- Deploy/Retrieve Mechanism
- Sensors
- Controls
- Power Source

Interface Requirements Discusison

(1) Deploy/Retrieve Mechanism - Cable must be maintained under tension between these two component assemblies at all times. An articulated levelwind may be required to facilitate BCA handling.

(2) Sensors:

Speed Control - Employ constant torque drive motor. Responds to Deploy/Retrieve Mechanism inhaul/outhaul speed demand by maintaining a T.B.D. cable tension.

Cable Scope - May employ RPMs count to achieve relatively high accuracy for scope measurement (refer to Section 1, Para. 1.1.5.3.1 for better approach).

(3) Controls:

If Hydraulic - Subplate Manifold Assembly required to interface control/status information to a Control/Indication Panel.

If Electric - A servo-controller w/DC Power Supply is required to interface (1) Solid State Drive and (2) a Control/Indication Panel.

(4) Power Source - Hydraulic or Electric, refer to (3) above for Speed Control discussion. Refer to Section 3, Part 1 for discussion on imposed loads/Hydraulic Power Supply adequacy.

2.1.5.4 A Pros and Cons Summary for each candidate configuration is presented in Figure 2.1.5.4.

Mechanism	Pro	Con
• CHETSA Concept	• Very small envelope requirements • Excellent low tension windup configuration • Very simple • Adaptable to 4" OD x 4' long Antenna elements (7 ea)	• Large O.D. • Flange design difficult to meet MIL-S-901C shock survivability
• W/Levelwind	• Incorporates Deploy/Retrieve Mechanism capabilities as "Direct Windup". Leads to an extremely simple System Configuration	• System Envelope & Weight limitations may be exceeded • Relatively high forces imposed on the B.C.A. • Antenna Element placement limited to last 1/5 or 1/6th of the B.C.A. length.
• Pressure Proof Access Trunk	• Eliminates dynamic seals and staging tube	• Exceeds System Envelope & Weight requirements • Very high installation impact/difficulty
• Barrel Stuffing	• "Zero" tension, and shear loading, w/largest bend radius permitted • Lightweight	• Free-flood environment desirable, i.e., PPAT configuration, or Aft Ballast Tank

Figure 2.1.5.4. Pros & Cons Summary Vol II, Section 2 Storage Assembly

2.2 DISCUSSION

2.2.1 Tradeoff Summary Chart(s) Figure 2.2.1(a) & 2.2.1(b) Explanation

The first chart Figure 2.2.1(a) depicts the values derived in the Evaluation Criteria Analysis, Section 5. The second chart, Figure 2.2.1(b) depicts the final numerical summary, with values generated as follows:

(a) Select optimum value in each of the successive columns.

(b) Normalize all other values in that column against the optimum value.

(c) Apply the appropriate weighting factor, i.e., CID evaluation criteria @ Base; Requirement @ 2X Base; and Goal @ 3X Base.

(d) Sum the horizontal rows to generate the intermediate Subtotal and the final Grand Total.

2.2.2 Ranking Summary

(a) Mean Value = 28.34; Standard Deviation = 5.48.

(b) Ranking according to highest value -- with significant difference equal to 1 Standard Deviation from the maximum Ranking Values:

CHETSA Concept	-	1st @ 34.99
Barrel Stuffing	-	1st @ 32.05
($>1\sigma$) w/Levelwind	-	2nd @ 25.20
$>2\sigma$ w/PPAT	-	3rd @ 21.12

2.2.3 Analysis of Results

As can be seen from the ranking summary, a statistical tie for primary consideration exists. However, the following factors must be noted.

(a) The Barrel Stuffing Concept requires an inordinate amount of envelope volume vs its form, fit, functional capability.

(b) The Barrel Stuffing Concept imposes a free-flood environment requirement for optimum storage/handling of the Buoyant Cable Assembly. The CHETSA Concept is amenable to either free-flood or atmosphere environment.

	Allocated Evaluation Criteria	CHETSA	Storage Assembly with Levelwind	PPAT	Barrel Stuffing
SOW Requirements					
R1	Positive-Self Sealing	N/A	N/A	N/A	N/A
R3	Airborne Noise/Structureborne Noise	2	1	1	2
R5	Imposed Shear Stress/Tensile Stress	9.78/302	9.78/3016	9.78/3016	1.02/ 100
R6	Installation Compatibility	3	2	1	1.5
R7	Envelope <85 Ft^3	42.85	70.13	>85	110/25
R8	Maintainability/Accessibility	3/3	3/2	2/1	1/1
R7&14	Inline Connectors & Cable Size				
R10	Cable Construction & Materials	.65 → 4.0	.65 → 4.0*	.65 → 4.0*	.65 → 4.0
R11	Antenna Element Size >4 in. x 4 ft				
R12	Storage Capacity 3000 → 5000 ft	5000	5000	5000	5000
R13	Static Load Capability >6000$\#_f$	10,000	10,000	10,000	-
R15	FPM Capability to 200	X	X	X	X
R16	Dynamic Load Capability to 3000$\#_f$	300	1000	1000	100
R19	Weight <3500$\#_f$	1887	1613	6000	1336
R20	Maximum HP Required	2.06	6.85	6.85	<1.0
R20	Power Source Required	Hyd./Elec.	Hyd./Elec.	Hyd./Elec.	Hyd./Elec.
SOW Goals					
G1	Variable Cable Dia., .50 → 1.00 in.	X	-	-	-
G2	FPM Capability to 400	X	X	X	X
	SUBTOTAL				
CID Evaluation Criteria					
-	No. of Components	6	13	14	6
-	Inherent Reliability, MTBF	>10,000	>5,000	2,500	5,000
-	Development Cost X $1,000	124	202	370	202
-	Cable Contact Efficiency	1 Pt.	2 Pt.	2 Pt.	1 Pt.
-	μ Dependence	.021	.063	.063	.021
-	Fatigue/Wear Impact	2	1	1	3
-	Producibility	3	2.5	2	3
	GRAND TOTAL				

Figure 2.2.1(a). Storage Assembly Tradeoff Summary Chart

		Storage Assembly			
	Allocated Evaluation Criteria	CHETSA	with Levelwind	PPAT	Barrel Stuffing
SOW Requirements					
R1	Positive-Self Sealing	N/A	N/A	N/A	N/A
R3	Airborne Noise/Structureborne Noise	2	1	2	2
R5	Imposed Shear Stress/Tensile Stress	.43	.14	.14	.2
R6	Installation Compatibility	2	1.33	.67	1
R7	Envelope < 85 Ft^3	2	1.22	.57	.78
R8	Maintainability/Accessibility	.2	1.67	.83	.66
R9&14	Inline Connectors & Cable Size				
R10	Cable Construction & Materials	2	1.5	1.5	2
R11	Antenna Element Size > 4 in. x 4 ft				
R12	Storage Capacity 3000 → 5000ft	2	2	2	2
R13	Static Load Capability > $6000\#_f$	2	2	2	2
R15	FPM Capability to 200	2	2	2	2
R16	Dynamic Load Capability to $3000\#_f$	2	1.33	1.33	2
R19	Weight < $3500\#_f$	1.42	1.66	.44	2
R20	Maximum HP Required	.97	.29	.29	2
R20	Power Source Required	2	2	2	2
SOW Goals					
G1	Variable Cable Dia., .50 → 1.00 in.	3	-	-	3
G2	FPM Capability to 400	3	3	3	3
	SUBTOTAL	28.99	22.20	18.12	26.05
CID Evaluation Criteria					
-	No. of Components	1	.46	.43	1
-	Inherent Reliability, MTBF	1	.5	.25	.5
-	Development Cost X $1,000	1	.61	.34	.61
-	Cable Contact Efficiency	.5	1	1	.5
-	μ Dependence	1	.33	.33	1
-	Fatigue/Wear Impact	.67	.33	.33	1
-	Producibility	1	.83	.67	1
	GRAND TOTAL	34.99	25.20	21.12	32.05

Figure 2.2.1(b). Storage Assembly Tradeoff Summary Chart

2.2.4 Recommendations

2.2.4.1 Select the CHETSA Concept as the primary candidate offering the best possibility of meeting the Requirements/Goals, and having the least development risk.

SECTION 6

VOLUME II, SECTION 3

CABLE GUIDE STUDY

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VOLUME II, SECTION 3, PART 1 - CONDUIT/GUIDE TUBE STUDY

SECTION 3

CABLE GUIDE STUDY

PART 1

CONDUIT/GUIDE TUBE STUDY

3.1.1 INTRODUCTION

3.1.1.1 Definition

The conduit must have a smooth clean bore large enough to pass the maximum diameter of the antenna elements. It should be smooth to reduce the retrieval friction losses. By minimizing the total bends in the tube, the friction loss will be also reduced.

3.1.1.2 Problem Areas

Measurements on CHETSA conduit indicate that the coefficient of friction between rubber or plastic jacketed cable and suitable metal tubes may be as high as .55. This friction in the conduit results in an increase in the force required to pull an antenna through the tube, or a multiplication factor which must be applied to the drag force on the antenna. This multiplication factor is also related to the amount of bend angle by the formula for capstans or drag brakes as follows $\frac{T_2}{T_1} = e^{\mu\alpha}$ where T_1 is the outboard or drag tension, T_2 is the inboard tension required to cause the antenna to move, μ is the friction coefficient and α is the total bend angle in radians.

For the average installation of an antenna system, the total bend will be about 90° or $\frac{\pi}{2}$ radians to get from a vertical exit through the hull to a horizontal exit from the sail. With the friction coefficient indicated above, this results in $\frac{T_2}{T_1} = e^{.55 \times \pi/2} =$ 2.372. Thus the drag values shown in Figure 3.1.1.2 must be multiplied by this factor in order to determine the tension which must be applied at the inboard end of the antenna in order to pull it in. When applying Figure 3.1.1.2 it must be remembered that the actual outboard retrieval tension or drag tension depends on the ship speed plus the retrieval speed. Thus for every 100 feet/min. of retrieval speed the total antenna speed must be

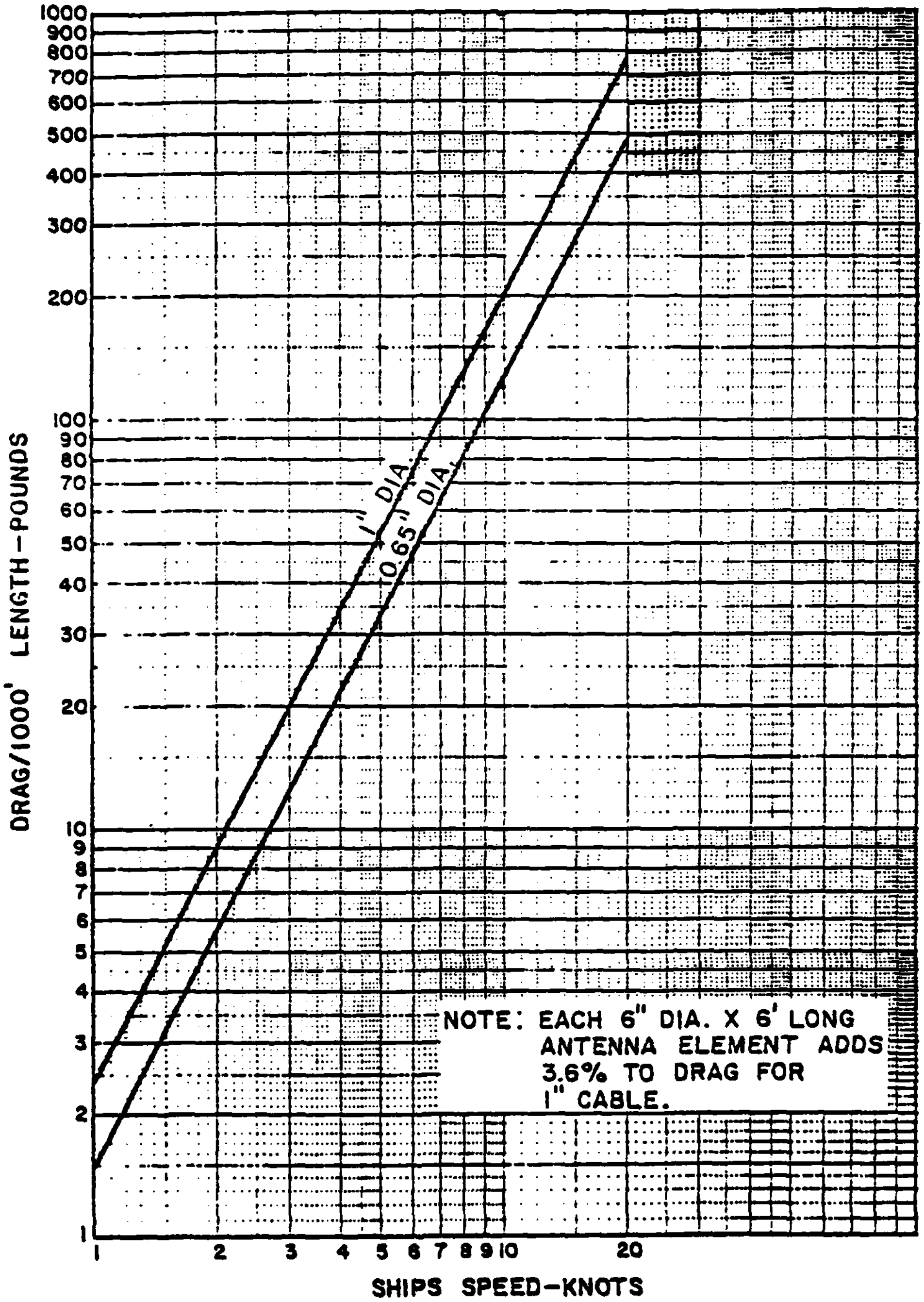

Figure 3.1.1.2. Drag Versus Speed in Knots for Various Antenna Configurations

increased by one knot. Therefore in haul at 400 ft/min. at 10 knots is equivalent to the drag for 14 knots tow speed.

As can be seen, the available dynamic load capability of the system is extremely sensitive to the amount of guide tube bend angle, and to the friction coefficient. The only means by which this effect can be negated are (1) by placement of the Deploy/Retrieve mechanism exterior to the pressure hull. (However, location of the Deploy/Retrieve Mechanism outboard violates Requirement 8 of the SOW); and (2) installation of an outboard idler sheave, placed so that the total bend angle can be significantly reduced.

The important considerations for the guide tube are:

- Corrosion/Fouling must be addressed vis-a-vis material selection.
- Diameter, shape, smoothness and length must be defined.
- $6000\#_f \rightarrow 10{,}000\#_f$ static tow load must be sustained by the Conduit/Guide Tube structural support assembly.

3.1.1.3 Requirements

3.1.1.3.1 The allocated Requirements and Goals to the Conduit/Guide Tube are as shown in Figure 3.1.1.3.1. Refer to the Discussion Para. 3.1.2 for analysis and recommendation. Additional CID evaluation criteria which were employed are:

a. No. of Components - determine relative complexity.

b. Inherent Reliability - determine a characteristic MTBF.

c. Development Cost - determine relative budgetary cost estimate to produce a working prototype (incl. drawings).

d. Cable Contact Efficiency - characterized determination of cable handling method, and the consequent potential degree of impact on the cable structure geometry.

e. Friction Dependence - evaluation of the susceptibility of performance degradation based upon environmental friction characteristics variability vs a minimum required by the particular mechanism to transmit energy into the cable assembly system.

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DRSS SOW REQUIREMENTS/GOALS
ALLOCATION TO COMPONENT LEVEL

COMPONENT	REQUIREMENTS	GOALS
• TOW/EXIT POINT	4, 5, 6, 10, 11, 13, 14, 15, 16	1,2,3
• CABLE GUIDE -		
- CONDUIT	4, 5, 6, 9, 10, 11, 13, 15, 16	
- SEALS & VALVES	1, 2, 3, 4, 5, 6, 10, 11, 14, 18	1
- CABLE/ANTENNA ELEMENT SHEAR DEVICE	1, 2, 4, 6, 9, 10, 11, 14, 20	
• DEPLOY/RETRIEVE MECHANISM	3, 4, 5, 6, 8, 9, 10, 11, 13, 14, 15, 16, 18, 20	1,2,3,5
• STORAGE ASSEMBLY	1, 3, 5, 6, 8, 9, 10, 11, 12, 13, 15, 16, 20	1,2,3,5
• SENSORS	1, 4, 5, 6, 9, 10, 11, 12, 14, 15, 16, 17	1,2,3,4
• CONTROLS	3, 6, 15, 17, 18, 20	2,3,4,5
• POWER SOURCE	3, 6, 8, 15, 16, 20	2,3
• ANTENNA/RF INTERFACE	1, 2, 4, 5, 9, 10, 11, 12, 13, 14, 15, 16, 17	2,3,4

NOTE: (1) REQUIREMENTS #7 & 19 ARE APPLICABLE TO ALL OF THE ABOVE.

Figure 3.1.1.3.1. DRSS SOW Requirements/Goals Allocation to Component Level

f. Fatigue/Wear Impact -characterized determination of the cable handling method, and the consequent impact on cable structure failure.

g. Producibility - relative estimate of degree of difficulty in fabrication/assembly and qualification test of the particular mechanism analyzed.

3.1.1.3.2 All allocated Requirements/Goals and CID evaluation criteria are employed to determine useability of the component configuration analyzed and are listed in Section 5.

3.1.1.4 Analytical Approach

The candidate concept configuration is analyzed/characterized to the extent necessary in the Discussion Para. 3.1.2, to assess whether or not each evaluation criteria (Allocated Requirements & Goals) can be met. CID evaluation criteria are imposed to ascertain: (1) factors impacting on engineering or manufacturing feasibility and (2) Unit production cost factors which will be used as the basis of Design to Cost evaluation at the Systems Level, Volume 1, a Recommendation is made based upon the results of the evaluations.

3.1.1.5 Candidate

3.1.1.5.1 The candidate approach selected for evaluation is a Monel 400 Guide Tube, with ID 4 inches. A detailed configuration description and consideration(s) overview is presented in the Discussion Para. 3.1.2.

3.1.1.5.2 The Conduit/Guide Tube interfaces with the following:

- Tow/Exit Point
- Pressure Hull Penetration Point
- Seals & Valves
- Sensors

Interface Requirements Discussion

(1)	Tow/Exit Point:	Rigid Joint not possible articulation clearance of $>$ 1/4 in. recommended to permit the Tow/Exit Point Bellmouth assembly to pivot for accommodation of the B.C.A. flight angle. Refer to Section 4 for a detailed explanation.
(2)	Pressure Hull Penetration Point:	Rigid, leakproof joint required at $>$ 1500 psid proof pressure.
(3)	Seals & Valves:	Rigid, leakproof joint(s) required at $>$ 1500 psid proof pressure.
(4)	Sensors:	End termination, B.C.A. diameter sense and possible "connector count" sensors must be inserted into the Conduit/Guide Tube to assure positive DRSS control/feedback interface to B.C.A. handling for deployment and retrieval operations.

3.1.1.5.3 Pros & Cons Summary

Mechanism	Pro	Con
• Conduit/Guide Tube	-	• Mandatory - to achieve Reqt. 8 • Large Dia. impacts on B.C.A. buckling

3.1.2 DISCUSSION

3.1.2.1 Characterization of the Conduit/Guide Tube

- Configuration: Sized to accept 4 in. OD x 4' long antenna elements with the 0.65D B.C.A.
- Interfaces:
  (1) Outboard -- to the Tow/Exit Point
  (2) Inboard -- to the hull valve and through all required Valving to the Deploy/Retrieve Mechanism and Storage Assembly.
- Considerations:
  (a → e) Materials selection, re corrosion resistance and minimized coefficient of friction. Include Test Results.
  (f) Total degrees of bend required.
  (g) Structural requirements.
  (h) Loading imposed on the B.C.A.
  (i) Location, re Tow/Exit Point.
  (j) Heat transfer requirements.

3.1.2.2 Analysis of Considerations

(a) Based upon CHETSA program test results, two materials selection approaches are possible. Because of corrosion resistance and low coefficient of friction, copper nickel 9010 or Monel 400 are excellent, but expensive options. A cheaper approach is to use a plain steel tube with a teflon liner. This has a significantly lower coefficient of friction. However, preliminary test data shows that it may be susceptible to unacceptably hgh wear rates.

Analysis of CHETSA test results indicates the following: Refer to Figure 3.1.2.2.

1. The Coefficient of Friction between 100 → 210# is reduced by a value of approximately 0.1, with the dynamic value approximately 0.05

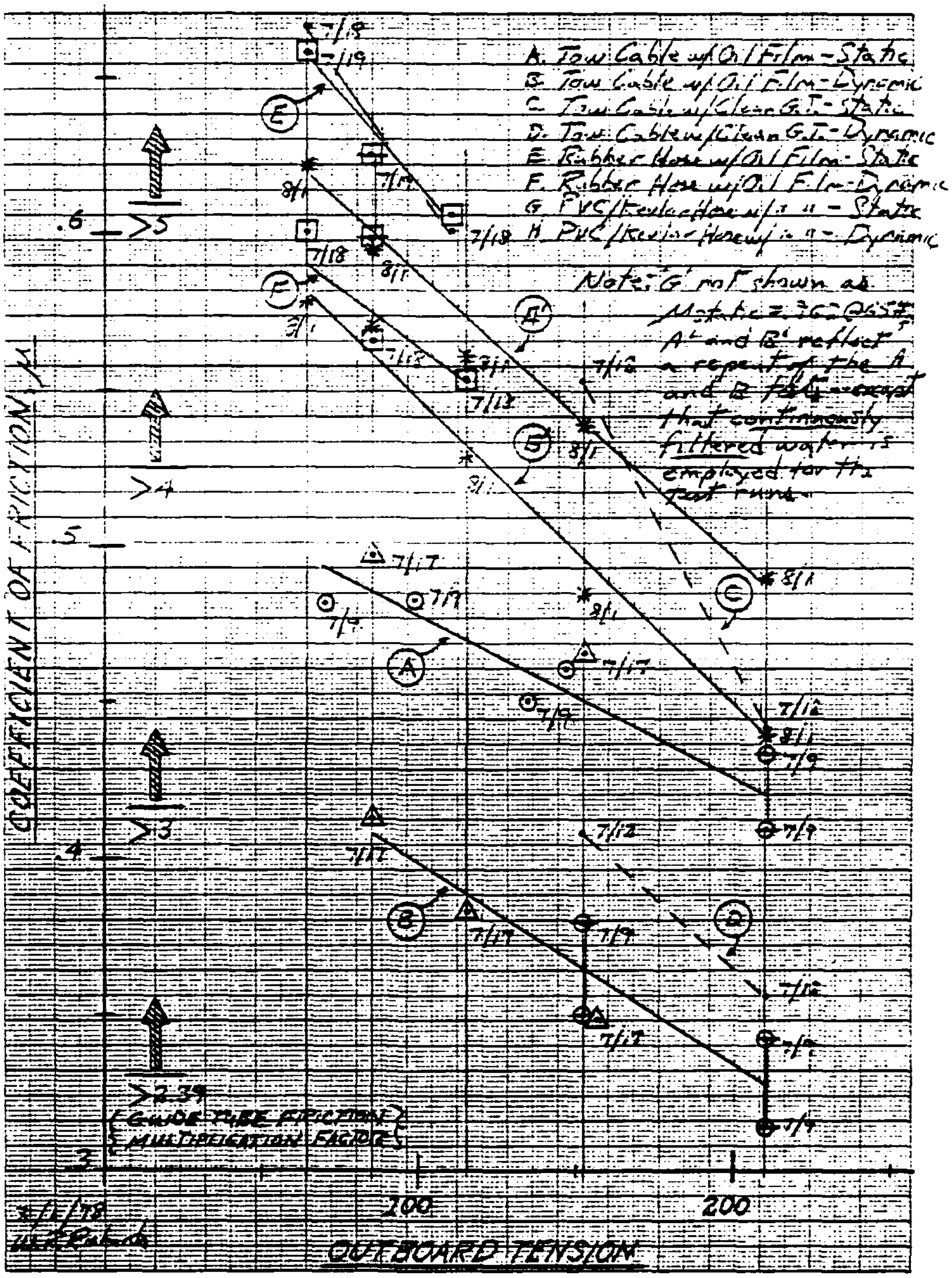


Figure 3.1.2.2. CHETSA Test Results

between that of the static for highly filter water, with final values of 0.49 (static) and 0.44 (dynamic) @ 210# for rubber jacketed tow cable 1.10 in. OD in a Monel Guide Tube of 1.50 in. I.D. and 151° total bends.

2. Under the same test conditions, except that an oil film was generated within 20 minutes of filtration termination, we saw a reduction in the final coefficient values to 0.42 static and 0.33 dynamic.

3. PVC/Kevlar reinforced array hose and rubber array hose w/o circumferential reinforcement (which flattens under load, show a higher than predicted coefficient. Results are less certain, due to "stickshin" inducing measurement anomalies.

(b) Assuming that, due to the lack of hard test data for the B.C.A. jacket material, and of higher loads, the coefficient of friction doesn't reduce further, and that a rubber jacket will provide higher friction than that of a polyethylene jacket, a "best estimate" for the coefficient of friction will be 0.42 → 0.49 static and 0.33 → 0.44 dynamic.

(c) The above coefficients of friction are employed in the Euler Relation, along with the estimated total degrees of bend (in radians) to determine the outboard tension multiplication factor which would, in turn, determine the imposed inboard tension that would be required for retrieval. Note deployment outboard tensions will be divided by this same factor to determine the imposed inboard tension.

(d) As the DRSS will operate at loads of 3000# → 6000# that is, >15X the current CHETSA test conditions, it is essential that these friction values be verified. The assumption of a lower limit as described in (c), based on values measured at $210\#_f$ and extrapolated to 3000# and higher, is considered to be conservative. Since the Conduit/Guide Tube friction multiplication factor is critical to optimization of DRSS performance, with high risk implied in the large extrapolation (15X) current test data alternative backup approaches to *friction reduction must be investigated. Additionally, new test data will be* essential in order to validate the extrapolations very early in the experiment program.

(e) Three alternative options to friction reduction are considered as backup:

Option 1

Low pressure water injection - 10 ports/90° @ $\approx$ 15 psi for a 1/16th dia. orifice (very low noise generation) provides a 25% reduction in the static coefficient of friction for rubber array hose w/Monel tube (Figure 3.1.2.2(a); a 32% reduction for PVC/Kevlar array hose w/Monel tube (Figure 3.1.2.2(b), a 42% reduction for rubber array hose w/CuNi tube (Figure 3.1.2.2(c); and a 46% reduction for PVC/Kevlar array hose w/CuNi tube (Figure 3.1.2.2(d). The test configuration is depicted in Figure 3.1.2.2(e).

- The Option 1 approach would require a separate seawater pumping system capable of maintaining 15 psi above ambient sea pressure.

Option 2

Employ an outboard sheave to eliminate 90° of bend. The sheave pitch diameter would have to be approximately 4 ft.

- The Option 2 approach would require a significant amount of volume/weight and impact significantly upon Conduit Location/routing options -- such that the DRSS be within the superstructure yet provide interface with the Tow/Exit Point and the placement of the Deploy/Retrieve Mechanism within the pressure hull.

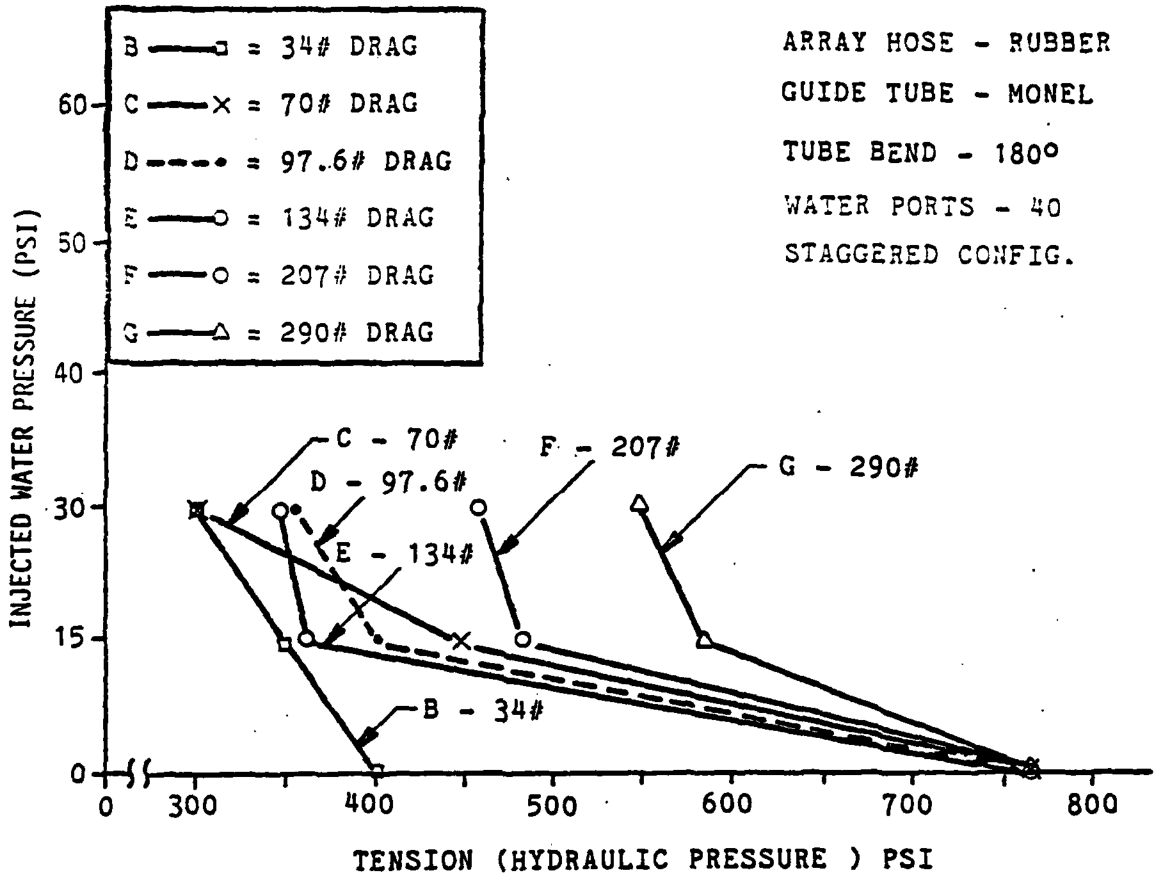
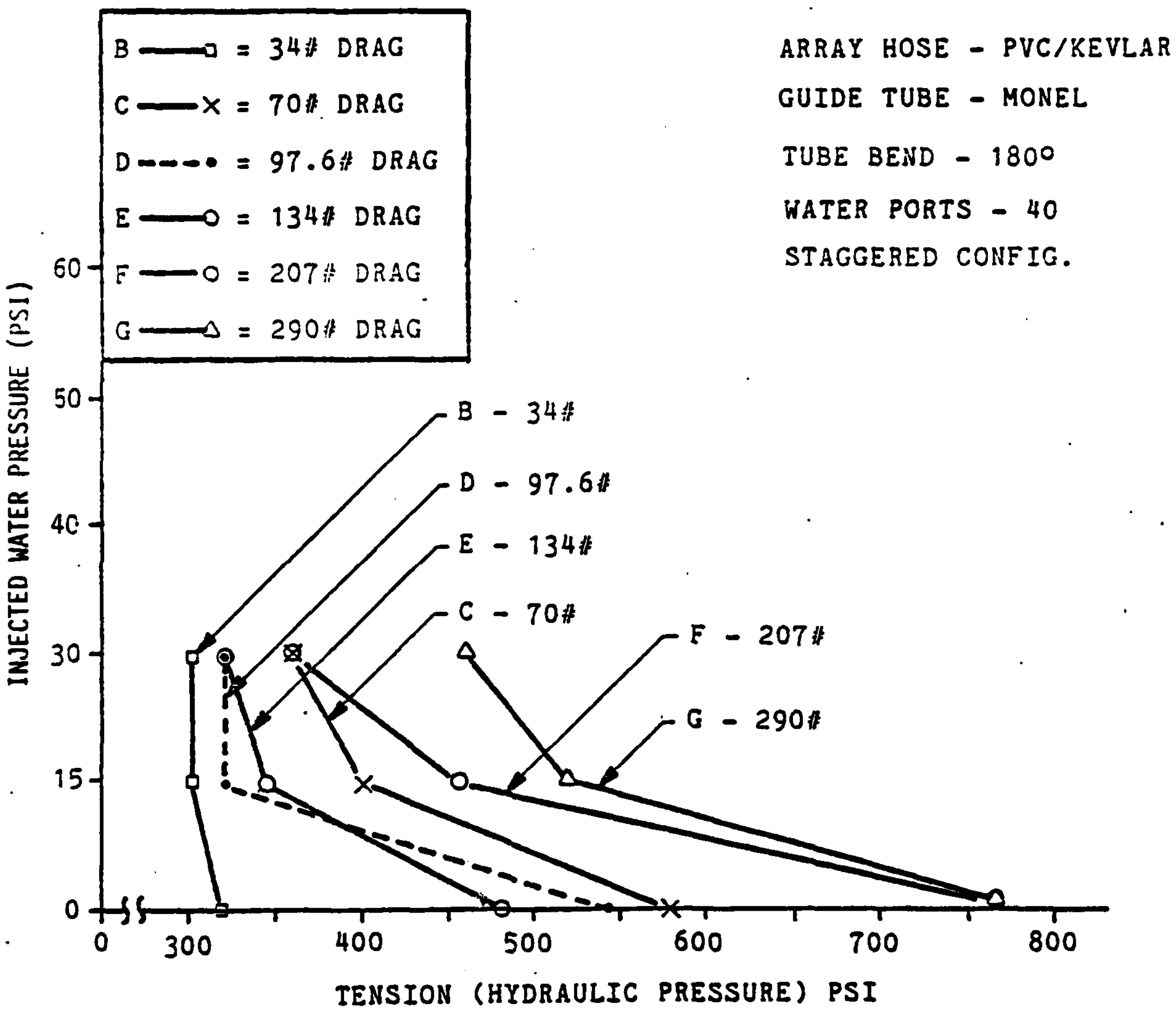


Figure 3.1.2.2(a). Option 1 Friction Reduction Results



NOTE 1. DATA POINT LIMITED TO TEST STAND CAPABILITY

Figure 3.1.2.2(b). Option 1 Friction Reduction Results

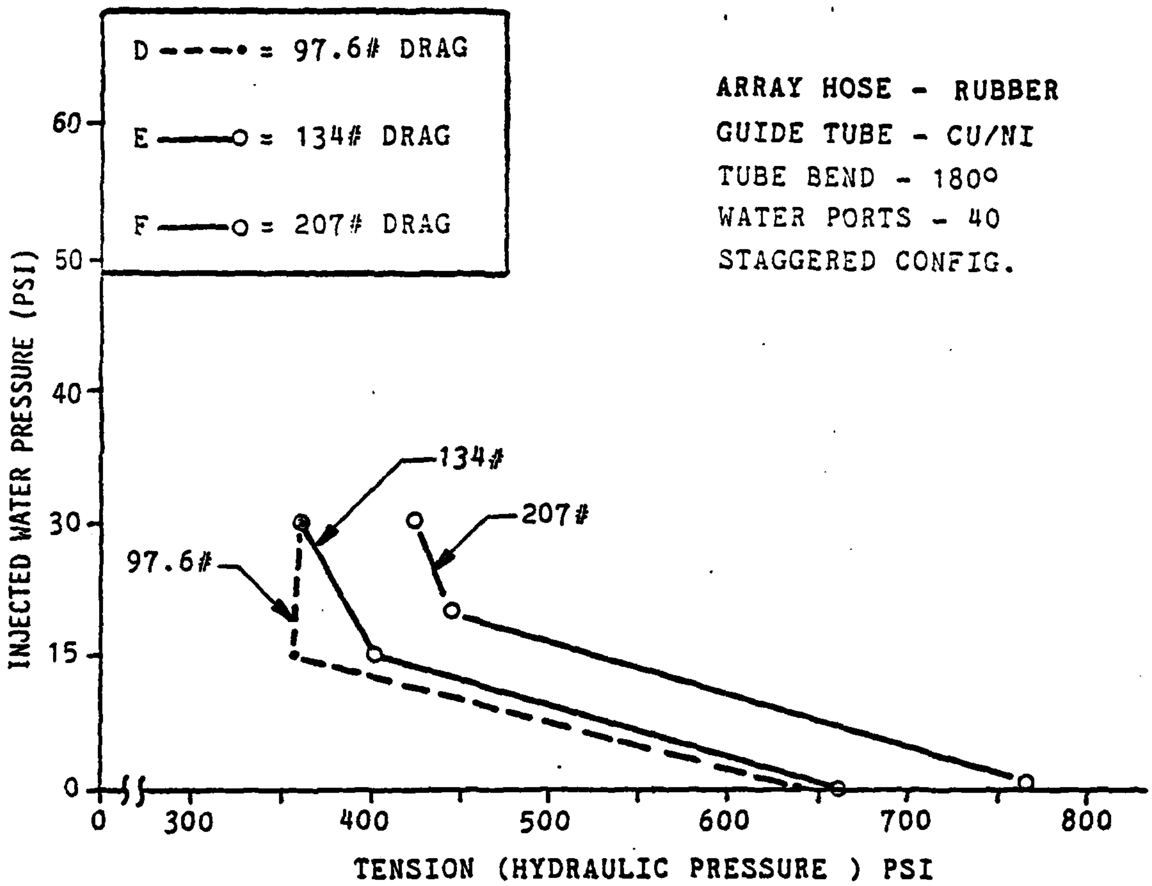


Figure 3.1.2.2(c). Option 1 Friction Reduction Results

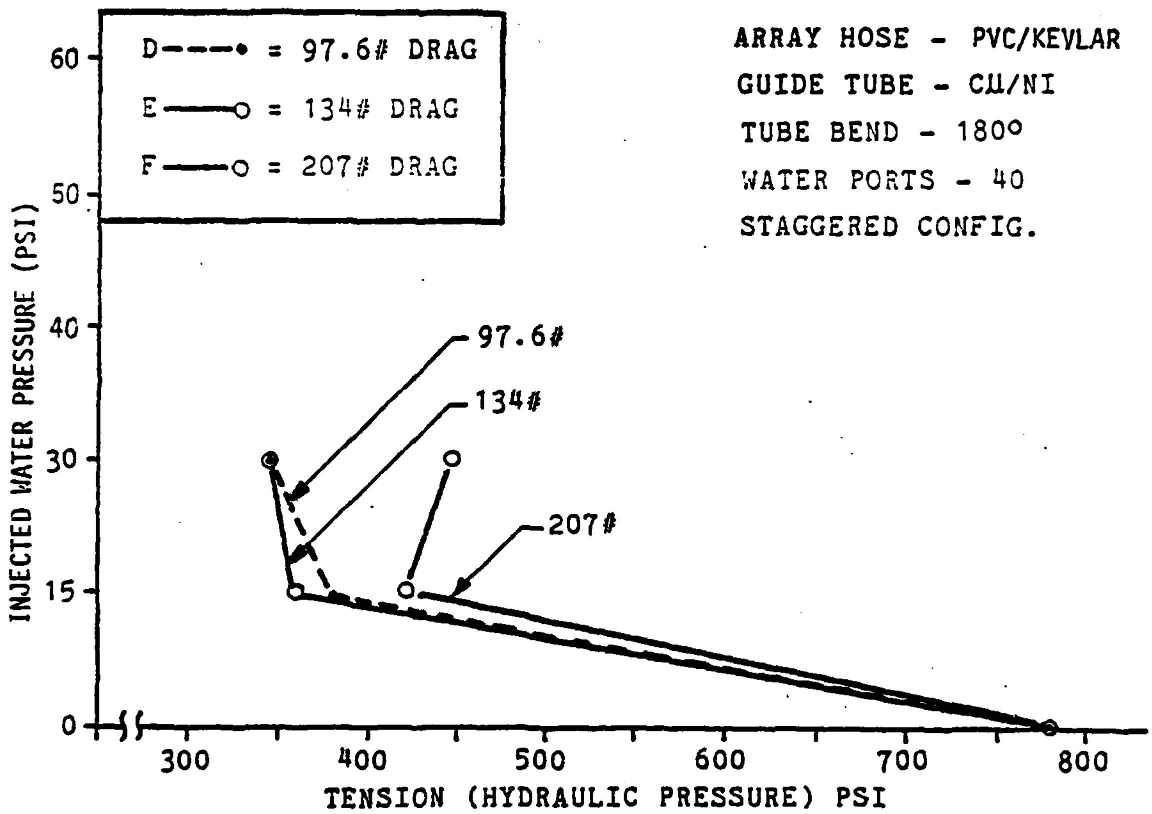


Figure 3.1.2.2(d). Option 1 Friction Reduction Results

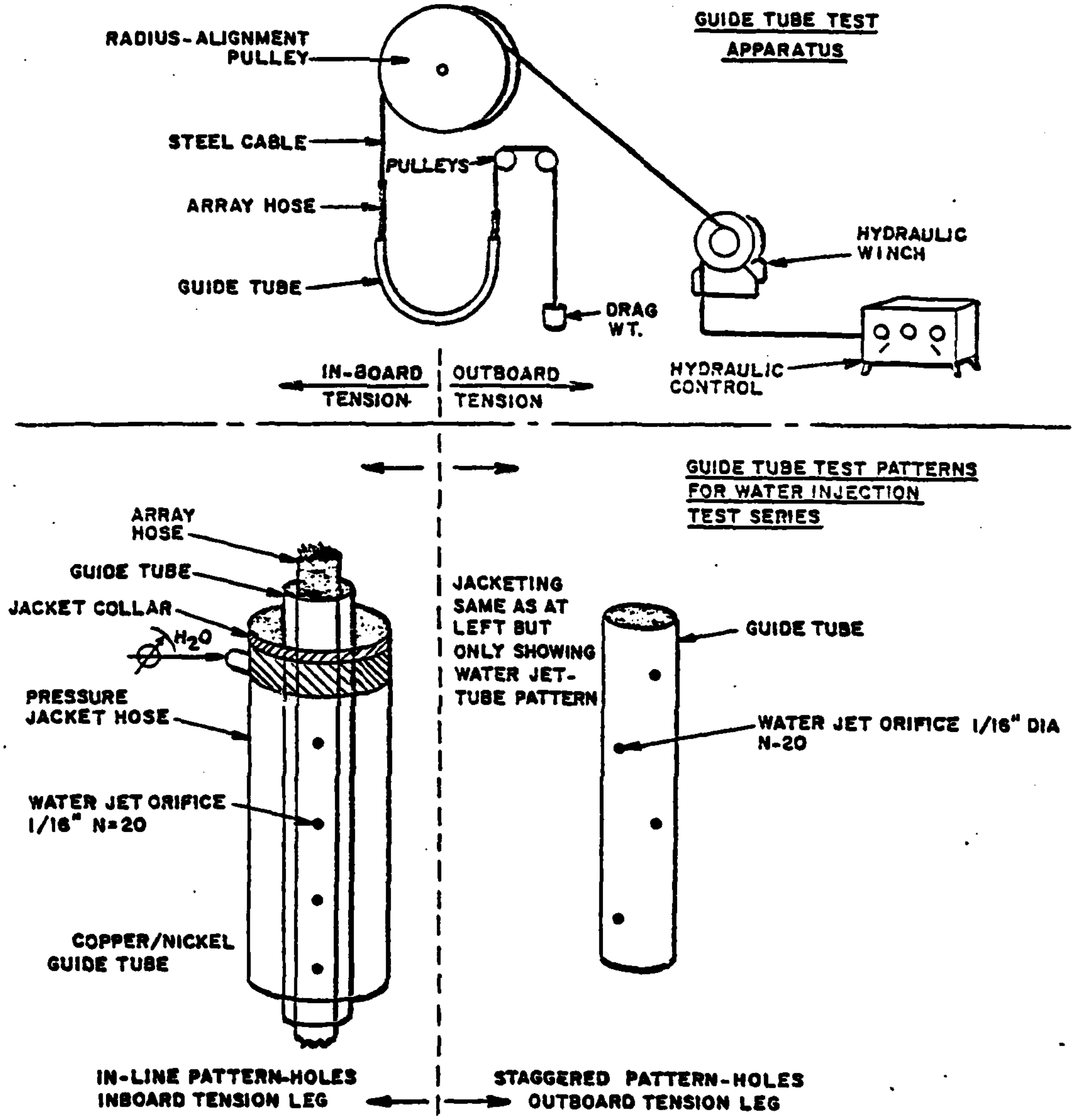


Figure 3.1.2.2(e). Option 1 Friction Reduction Test Configuration

Option 3

Place the Deploy/Retrieve Mechanism outboard in conjunction with the Tow/Exit Point.

- The Option 3 approach would have the additional impact of requiring that the Deploy/Retrieve Mechanism be outside the pressure hull boundary.

(f) The total degrees of bend required are, for the purposes of the DRSS study, set at 90°. This assumption is based upon existing BRA-24 and BRA-18 installation configuration(s). Refer to Figure 3.1.2.2(f), (g) and (h) for impact on system performance with respect to: (1) HP required for various operational conditions; (2) a technique for optimization of HP requirements; and (3) a Hydraulic Power Supply Adequacy Analysis. Actual routing for the system concept selected will determine the estimated degrees of bend required. This must be determined via a detailed investigation of each of the submarine class interface requirements vis-a-vis installed location -- which was not possible within the scope of the present study.

(g) Structural requirements indicate, for a 6000# (minimum) and 10,000# (maximum) static tow load, that an adequate factor-of-safety be employed in sizing of the conduit wall thickness and structural support point locations. A structural loading criteria of $\approx$1.5X the B.C.A. breaking strength is recommended.

(h) Loading on the B.C.A. shall be considered to be a combination of imposed shear loads (inboard tension-outboard tension)/linear arc-of-contact of the total bend and tensile loads due to the outboard tension.

- Per Appendix H, B.C.A. Depth Vs Speed Capability, assuming approximately a 20 knots speed, imposed loads at 5000 ft scope are 3535#, and @ μ = .40 for 90° bend the friction multiplication factor equals 1.492 (Ref. Figure 3.1.2.2(f). This yields an inboard tension of $5274\#_f$.

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HP MATRIX ENVELOPE CHART

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WRR

TRANSFER MECH. IMPOSED LOAD, #F	IDEAL HP reqd @ 200 FPM	IDEAL HP reqd @ 300 FPM	IDEAL HP reqd @ 400 FPM	CONFIGURATION FACTOR @ 90° G.T. BEND w/μ=: HP=1.280X (μ-0.25)	HP=1.492X (μ=0.40)	HP=2.380X (μ=0.55)
3000	18.18	27.27	36.36	23.27 34.91 46.54	27.12 40.68 54.24	43.27 64.91 86.54
4000	24.24	36.36	48.48	31.03 46.54 62.06	36.17 54.26 72.34	57.69 86.54 115.38
5000	30.30	45.45	60.60	38.78 58.17 77.56	45.21 67.82 90.42	72.11 108.16 144.22
6000	36.36	54.54	72.72	46.54 69.81 93.08	54.25 81.38 108.50	86.54 129.81 173.07

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Figure 3.1.2.2(f). HP Matrix Envelope Chart

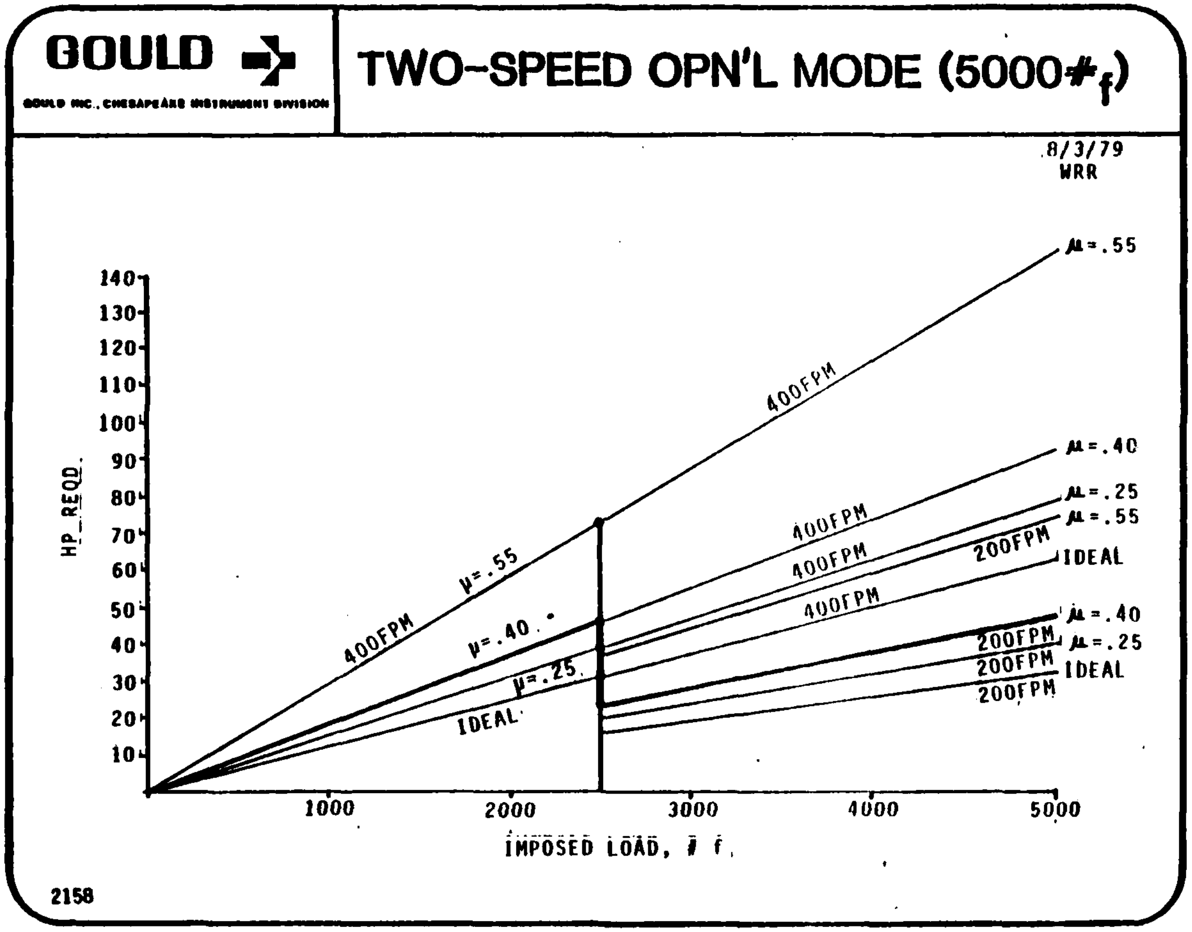

Figure 3.1.2.2(g). Two-Speed Operational Mode ($5000\#_f$)

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HYDRAULIC POWER SUPPLY ADEQUACY ANALYSIS

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- PER REQT 20, MAX. AVAILABLE HYDRAULIC POWER EQUALS 52.5 HP
- PER HP MATRIX ENVELOPE CHART, W/CONFIGURATION FACTOR θ/μ = .40 OF (1.492X IDEAL HP)

  --IDEAL HP @ 5000 $\#_f$ IMPOSED LOAD & 200FPM = 30.30

  --ESTIMATED HYDRAULIC DRIVE EFFICIENCY = .93
  --RESULTANT HP REQD. = 48.6
  --PER TWO-SPEED OPERATIONAL MODE CHART, AVERAGE INHAUL/OUTHAUL SPEED = 300FPM

- NOTE THAT 5000 $\#_f$ IMPOSED LOAD APPROX 3% GREATER THAN TOTAL DRAG OF A 5000 FT. ANTENNA, 0.65 DIA, @ SHIP SPEED ≃ 20 KNOTS

- THE TWO-SPEED OPERATIONAL MODE CAPABILITY IS INHERENT IN THE MOTOR/VALVE BLOCK CONFIGURATION FOR VARIOUS MANUFACTURERS OF HYD. MOTORS. MOTOR DISPLACEMENT IS ALTERED (OR REDUCED BY A FACTOR OF TWO) -- DOUBLING THE SPEED AND HALVING THE DELIVERY TORQUE. A SIMILAR TECHNIQUE MAY BE UTILIZED ON THE PMI SOLID-STATE TORQUE RING MOTOR.

2159

Figure 3.1.2.2(h). Hydraulic Power Supply Adequacy Analysis

Therefore the imposed shear loading is $1739\#_f$, distributed over a 90^o arc of contact. Assuming a minimum 2 ft radius, the 90^o arc of contact is 3.14 ft and the imposed shear loading is $553\#_f$/linear ft.

- Per Appendix G, Cable Analysis Tests, the 2% offset yield point is approximately $733\#_f$/ft, with the allowable yield point estimated at $613\#_f$/ft. As these values are only marginally greater than required, friction reduction, degrees of bend reduction, application of sheave, and/or consideration to placement of the Deploy/Retrieve Mechanism outboard must be made!

(i) Location with respect to the Tow/Exit Point placement, determines the outboard interface starting point. We assumed that the inboard interface termination point will be severely constrained with respect to possible locations (i.e., existing BRA-24 location and/or Aft ballast tank System Concept B and E respectively). Routing of the guide tube is critical and will be a major design driver with respect to configuration requirements. Employment of an outboard sheave to eliminate $60 \rightarrow 90^o$ of bend would provide latitude in routing the guide tube.

(j) Heat Transfer requirements are characterized for the conduit with respect to the differential loading calculated in (h) above.

$$HP_{loss} = \frac{1739\#_f \times 200 \text{ FPM}}{33000'\#/\text{Min-HP}} = 10.54 \text{ HP}$$

$$\& \ Q_{gen} = 10.54 \text{ HP} \times 42.4 \text{ BTUs/Min} = 446.9 \text{ BTUs/Min}$$

Per an equivalent analysis similar to that in Appendix O, where the B.C.A. was found to absorb >99% of the generated heat, the estimated thermal rise expected is found as follows, where absorbed heat will be approximately 14.3% of the total. (Reference Diagram below.)

Cable Mass = .795 Sp. Gr. x $62.4\#_{m/ft^{-3}}$ x 11.52 ft^3 (5000' of .65D cable)

= $751.3\#_m$

& $\dot{m}$ @ 200 FPM = $22.85\#_m$/Min.

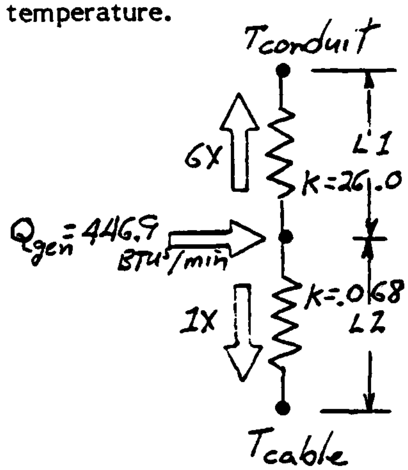
& Assuming C_p of the Polyethylene jacket is .55

$\therefore\ Q_{Gen} = \dot{m}\, c_p\ \Delta T$

& 63.8 BTUs/Min = $22.85\#_m$/Min x .55 BTUs/$\#_m$ x $\Delta T, {}^{\circ}F$

or $\Delta T, {}^{\circ}F_{\substack{\text{thermal}\\ \text{rise}}} = 5.1^{\circ}F$

This value will be significantly higher due to localized heating and the integrated effects of changing junction temperature drive potential increase along the arc-of-contact due to the higher cable jacket temperature/conduit temperature.



(A_s = 3.14' x 3/16"; = .05 ft^2)

(A_s = 200' x 3/16"; = 3.19 ft^2/Min.

Note - ratio of k, A_s indicates a 6:1 difference, assuming Ls are equivalent

The conduit thermal rise expected is similarly found as follows:

Conduit Mass, 1 in effective zone about the arc-of-contact = 3.14 ft x 1" wide x .25 wall thickness x $.3\#_m/in.^3$ = $2.83\#_m$; & C_p = .11

$Q_{Gen} = m\, C_p\ \Delta T$

& 383.1 BTUs/Min = 2.83#m (.11 BTUs/$\#_m$) x ΔT, ^oF/Min

$$\text{or } \Delta T, {}^oF/\text{Min}_{\text{thermal rise}} = 1231^oF/\text{Min}$$

However, this does not include the equilibration effect of rising junction temperature, where ---

$$Q_{\text{absorbed cable}} = \frac{k\ A_s}{L}\ \Delta T$$

$$@\ 446.9\ \text{BTUs/Min} = \frac{.068(3.19\ ft^2/\text{Min})}{.06''/12''/ft}\ \Delta T, {}^oF$$

$$= 43.384\ \text{BTUs/Min}, {}^oF\ (\Delta T, {}^oF)$$

$$\text{or } \Delta T_{Max} = 10.30^oF$$

Conclusion - The junction temperature jumps to +10.30°F within the first second and stabilizes @ <10.30°F cable jacket temperature for the remainder of the retrieval cycle!

3.1.2.3 Recommendations

(1) Test verification of extrapolated data is essential early in the experiment program.

(2) Viable options exist with respect to configuration alternatives for friction reduction.

(3) An outboard sheave may be required.

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VOLUME II, SECTION 3, PART 2 - VALVES STUDY

PART 2

VALVES STUDY

3.2.1 INTRODUCTION

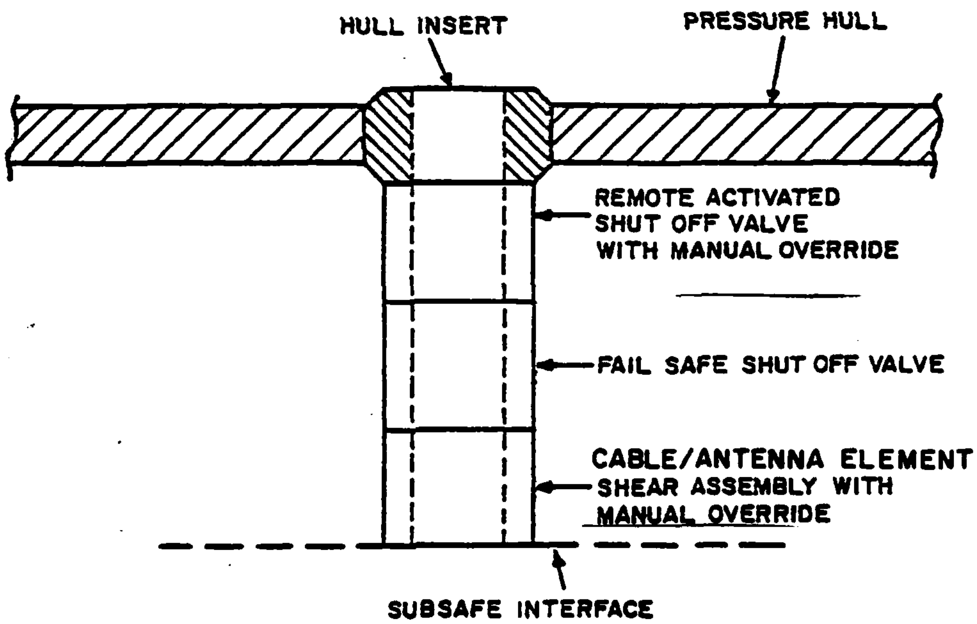
3.2.1.1 Definition

A valve is defined by the establishment of an effective leakproof interface to the Ship's pressure hull. SUBSAFE requirements call for two shutoff valves immediately inboard of the pressure hull insert, since its size must be greater than 1 inch and less than 7 inches.

Three types of valve functions are required, as follows:

- Hull Valve (HV) - a remote activated shutoff valve with manual override. Operational capability at great differential pressure over the full operating range of the submarine.
- Failsafe Shutoff Valve (FSV) - a locally activated shutoff valve with manual and remote override. Shall require redundant sensors to activate the valve whenever the Buoyant Cable Assembly is not present in the valve port envelope -- redundant valve position sensors to assure local and remote status feedback -- and redundant power source and/or Failsafe closing ("Spring applied" - power to open) in conjunction with activation of the Cable/Antenna Element Shear Assembly. Pressure capability to be similar to the Hull Valve.

- Cable/Antenna Element Shear Assembly (CSA) - a remote activated assembly with manual override; to be located inboard of the Failsafe Shutoff Valve so that it provide means to shear and permit clearing of the Buoyant Cable Assy from the Valving and Conduit/Guide Tube past both the Fail-safe Shutoff and Hull Valves. It should have the same operating and static pressure capability as the Hull Valve and/or Failsafe Shutoff Valve.



3.2.1.2 Problem Areas

A minimum hull penetration (bore of 4.37 inches) will be required to meet minimum DRSS requirements for handling 4.0 inch diameter antenna elements. The specific SUBSAFE requirements must be resolved through review of the preliminary concepts defined in this study by cognizant Navy personnel at the direction of NUSC and NAVELEX.

- We believe that the valve body envelope is, an area not accessible for cable support. The consequent unsupported length provides susceptibility to cable buckling. Current calculations indicate that for a .65 diameter cable a maximum unsupported length must be less than 6.5 inches. The port face-to-face dimensions are therefore limited to less than this value.
- We investigated commercially available valving, and found that bore sizes are related to pipe sizes. In respect to DRSS requirements, typical capability is listed as follows:

Option A - AF 51; ANSI CL300: Ball Valve

Pipe Size	Bore	Face-to-Face Length	Wt	Operating Pressure Capability
3"	2.5"	11.12"	39.7#	1000 psi
4"	3.25"	12.00"	62.2#	1000 psi
6"	4.37"	15.88"	125.2#	1000 psi
8"	5.69"	16.50"	184.1#	600 psi ?

Option B - Miser Short Pattern: Ball Valve

3"	2.50"	4.50"	21.0#	1000 psi
4"	3.25"	5.81"	34.0#	1000 psi
6"	4.37"	7.38"	64.0#	1000 psi
8"	5.69"	Data Unavailable		600 psi ?

Option C - Miser Titanium Series 49: Ball Valve

3"	2.50"	4.37"	22.7#	1000 psi
4"	3.25"	5.27"	33.0#	1000 psi
6"	4.37"	6.77"	57.2#	720 psi
8"	5.69"	9.02"	112.2#	720 psi

Option D - Clamp-Seal or Shear-Seal Rotary Valve: (New Concepts)

-	2.50"	3.5 ± .12"	40# ± 10	600 psi
-	3.25"	3.5 ± .12"	60# ± 15	600 psi
-	4.37"	3.5 ± .12"	100# ± 20	600 psi
-	6.37"	3.5 ± .12"	200# ± 40	600 psi

Note - (1) only Options B, C & D -- "flangeless" are feasible from a cable buckling unsupported length criteria of < 6.5 inches.

(2) a 6 inch O.D. Antenna Element capability is not readily commercially available -- and/or grossly violates (1) above (it would require a 10" Pipe Size equivalent valve). Only Option D would be feasible.

(3) Option D is provided for comparison purposes only. It indicates potential for valve developments directly related to DRSS requirements.

- Corrosion, vis-a-vis materials selection must be addressed.
- Fouling could be a major area of concern since it would seriously impact the actuating torque requirements for the valves.
- Sequencing time, sensor and seal interface and position status must be rigorously analyzed at the system level to assure viability of the concept configuration operational capability.

3.2.1.3 Requirements

3.2.1.3.1 The allocated Requirements and Goals to the Valves are as shown in Figure 3.2.1.3.1. Additional CID evaluation criteria which were employed are:

a. No. of Components - determine relative complexity.

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DRSS SOW REQUIREMENTS/GOALS
ALLOCATION TO COMPONENT LEVEL

COMPONENT	REQUIREMENTS	GOALS
• TOW/EXIT POINT	4, 5, 6, 10, 11, 13, 14, 15, 16	1,2,3
• CABLE GUIDE -		
- CONDUIT	4, 5, 6, 9, 10, 11, 13, 15, 16	
- SEALS & VALVES	1, 2, 3, 4, 5, 6, 10, 11, 14, 18	1
- CABLE/ANTENNA ELEMENT SHEAR DEVICE	1, 2, 4, 6, 9, 10, 11, 14, 20	
• DEPLOY/RETRIEVE MECHANISM	3, 4, 5, 6, 8, 9, 10, 11, 13, 14, 15, 16, 18, 20	1,2,3,5
• STORAGE ASSEMBLY	1, 3, 5, 6, 8, 9, 10, 11, 12, 13, 15, 16, 20	1,2,3,5
• SENSORS	1, 4, 5, 6, 9, 10, 11, 12, 14, 15, 16, 17	1,2,3,4
• CONTROLS	3, 6, 15, 17, 18, 20	2,3,4,5
• POWER SOURCE	3, 6, 8, 15, 16, 20	2,3
• ANTENNA/RF INTERFACE	1, 2, 4, 5, 9, 10, 11, 12, 13, 14, 15, 16, 17	2,3,4

NOTE: (1) REQUIREMENTS #7 & 19 ARE APPLICABLE TO ALL OF THE ABOVE.

Figure 3.2.1.3.1. DRSS SOW Requirements/Goals Allocation to Component Level

b. Inherent Reliability - determine a characteristic MTBF.

c. Development Cost - determine relative budgetary cost estimate to produce a working prototype (including drawings).

d. Cable Contact Efficiency - characterized determination of cable handling method, and the consequent potential degree of impact on the cable structure geometry.

e. Friction Dependence - evaluation of the susceptibility of performance degradation based on environmental friction characteristics variability vs a minimum required by the particular mechanism to transmit energy into the cable assembly system.

f. Fatigue/Wear Impact - characterized determination of the cable handling method, and the consequent impact on cable structure failure.

g. Producibility - relative estimate of degree of difficulty in fabrication/assembly and qualification test of the particular mechanism analyzed.

3.2.1.3.2 All allocated Requirements/Goals and CID evaluation criteria are employed to determine the relative ranking of the component configurations analyzed, in Section 5.

3.2.1.4 Analytical Approach

The candidate concept configuration is analyzed/characterized to the extent necessary in the Discussion paragraph 3.2.2, to assess whether or not each evaluation criteria (Allocated Requirements and Goals) can be met. Additional CID evaluation criteria are imposed to ascertain: (1) factors impacting on engineering or manufacturing feasibility and (2) unit production cost factors which will be used as the basis of Design to Cost evaluation at the Systems Level in Volume I. Finally, a Recommendation is made based upon the results of the evaluations.

3.2.1.5 Candidates

3.2.1.5.1 The candidates selected for the hull valve and the failsafe shutoff valve are as follows:

Candidate	Closest Analog/ Similarity	Refer to Concept Config.	Refer to Analysis
• Ball Valve	N/A	Figure 3.2.1.5.1(a→c)	Para. 3.2.2
• Rotary Shear-Seal Valve	"Barksdale Shear-seal"	Figure 3.2.1.5.1(d)	Para. 3.2.2
• Clamp-Seal Valve	BRA-24 Static Seal	Figure 3.2.1.5.1(e)	Para. 3.2.2

The candidate selected for the Shear Assy is as follows:

Candidate	Closest Analog/ Similarity	Refer to Concept Config.	Refer to Analysis
• Single Blade Ram	BRA-24 Shear Assy & AN/SQR-19 Cable Cutter	N/A	Para. 3.2.2

3.2.1.5.2 Each candidate operates on an entirely different principle, with characteristics unique to the valve isolation technique employed. The configurations depicted in the Figures 3.2.1.5.1(a → e) are utilized to establish the basis for analytical characterizations made in the Discussion Paragraph 3.2.2.

3.2.1.5.3 The Valves interface with the follow:

- Conduit/Guide Tube
- Controls
- Sensors
- Seals
- Power Source

Interface Requirements Discussion

(1) Conduit/Guide Tube: Must maintain structural integrity and leak tight boundary equal to that of the pressure.

(2) Controls: Must interface with the Control/Indication Panel for actuation and status condition.

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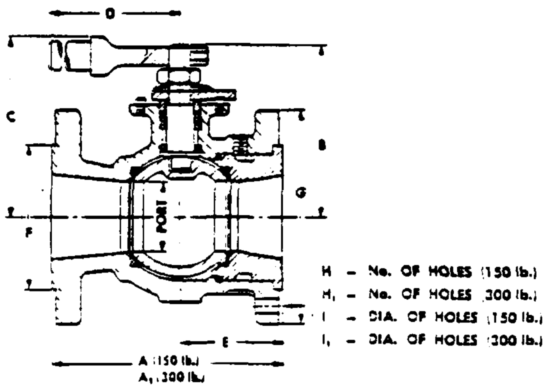
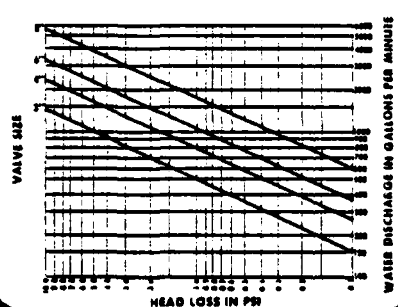
Specifics of the miser flanged ball valve

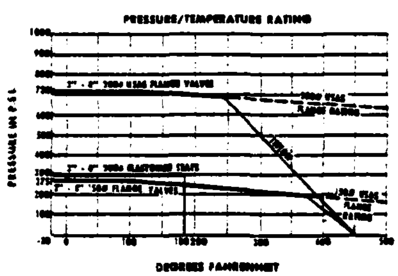


	DIMENSION												
SIZE	A	A_1	B	C	D	E	F	G	Port	H	H_1	I	I_1
3"	8	11⅛	5 11/16	6⅛	22¾	3⅜	5	7½	2½	4	8	¾	⅞
4"	9	12	5 3/16	5⅜	22¾	4	5 5/16	9	3¼	8	8	¾	⅞
6"	10½	15⅞	8 11/16	9¼	33¾	4¼	8½	11	4⅜	8	12	⅞	⅞
8"	11½	16½	10 1/16	10⅜	33¾	5⅜	10⅝	13½	5 11/16	8	12	⅞	1

Head loss vs. flow



Pressure-temperature rating



Ordering Code - Flanged Miser

Body, End Plug, Ball & Stem		Seats & Seals		USAS* or MSS Pressure Class
Ductile Iron	2	Buna	B	150# or
Carbon Steel	4	Teflon	T	300# length
316 s.s.	6	Reinforced Teflon	RT	

Note: Stainless steel flanged valves have flat face flanges per MSS specifications, all others have 1/16" raised face per USAS (formerly ASA) specifications.

Ordering example:

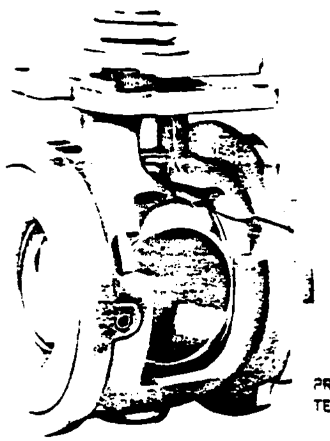
8" Carbon steel body, end plug, ball & stem, 150# flanged, with teflon seats and seals.

Size	Style	Body, End Plug	Ball & Stem	Seats/Seals	Type
8"	4	4	4	T	150

Order: 8" 444T-150

Figure 3.2.1.5.1(a). Miser ANSI CL300 Ball Valve

"Two valves in one"... the ultimate in piping flexibility



PRESSURES UP TO 1000*** psi WOG
TEMPERATURES UP TO 450°F.

1. Miser* Short Pattern Ball Valve

The Miser Short Pattern serves as "2 valves in 1". The center section is simply and quickly inserted between *two standard flanges* (either 150# or 300#) and the flanges bolted together. Almost any media within the temperature-pressure limitations can be handled by the short pattern Miser because it offers a wide choice of seats, seals and body materials. Both the Miser 151 and Miser 301 are available specially adapted for either oxygen or high-vacuum service.

Original costs are less and maintenance is less with the Miser Short Pattern. Yet, this valve offers you all the unique advantages of the standard Miser: the downstream seat sealing, lower torque, longer life, bottom entry blow-out proof stem with the adjustable self-compensating *stem feature of Misers. Unique design end-plug for easy field maintenance. Machining of retaining grooves allows random assembly of end plug.* No presses are required. Design provides uninterrupted gasket surface permitting use of all standard type gaskets.

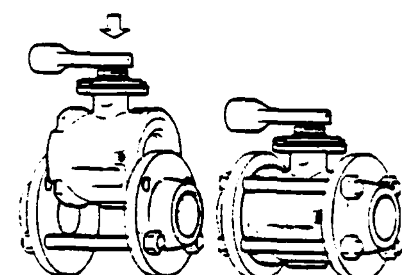
You get positive shut-off, easier operation, longer valve life and faster maintenance if necessary when you use Miser Short Pattern Ball Valves.

*Trademark of Worcester Valve Co., Inc.

Minimum Space Requirements-Check This!

The weight of Miser Short Patterns is 40% to 60% less than conventional USAS** ball valves. Their configuration is a lot more compact, too. The center to top dimension of a 4" Miser is only 6 3/16" as opposed to 27 3/4" for a standard gate valve . . . valuable space savings to original equipment manufacturers and in new installations.

**USAS formerly ASA
***720 psi for bronze and aluminum



The Miser Short Pattern is simply and quickly inserted between two standard flanges as shown. Correct studs and nuts furnished with valve.

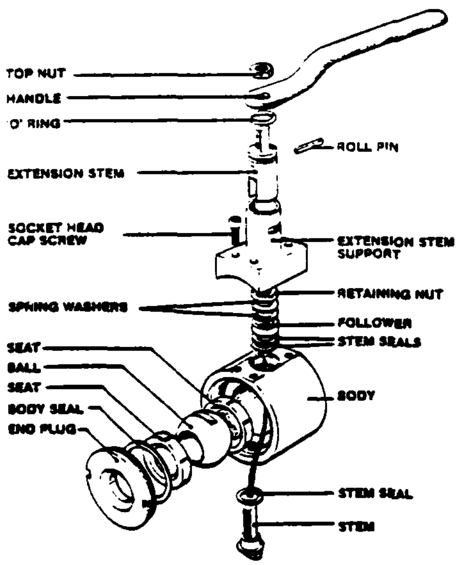
Figure 3.2.1.5.1(b). Miser Short Pattern Ball Valve

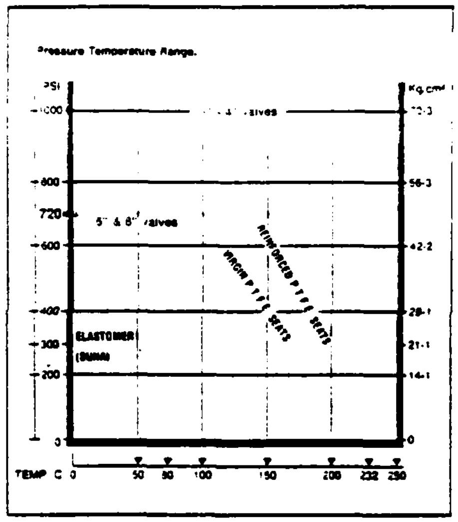
Series 49

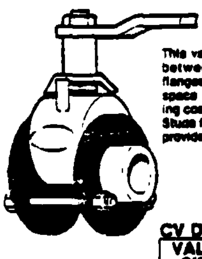
The unique wafer design of Worcester's Series 49 titanium ball valve uses minimum wetted surfaces, and features the Miser sealing package, resulting in high performance at minimum material cost.

Now you can enjoy all the advantages of the famous Miser ball valve in corrosive service beyond the capabilities of conventional ball valves:

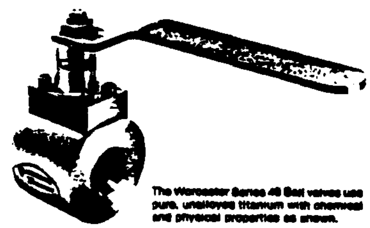
- Leaktight shutoff
- Bottom entry system
- Quarter-turn operation
- Compact
- Visual indication of valve position
- Easily automated







This valve is designed to fit between standard #150 flanges, with a minimum space requirement, effecting cost and weight savings. Studs for flange make up are provided with the valve.



The Worcester Series 49 Ball valves use pure, unalloyed titanium with chemical and physical properties as shown.

CV DATA

VALVE SIZE	CV (GPM)
½"	8
¾"	12
1"	32
1½"	80
2"	104

Chemical		Mechanical	
125 (Grade 1)		125	
20 max	Oxygen	25-38 tf/ins.²	Tensile Strength
10 max	Carbon		
03 max	Nitrogen	15 tf/ins.²	Proof Stress
013 max	Hydrogen	19%	Elongation
20 max	Iron		
Balance	Titanium		

Figure 3.2.1.5.1(c). Miser Titanium Series 49 Ball Valve

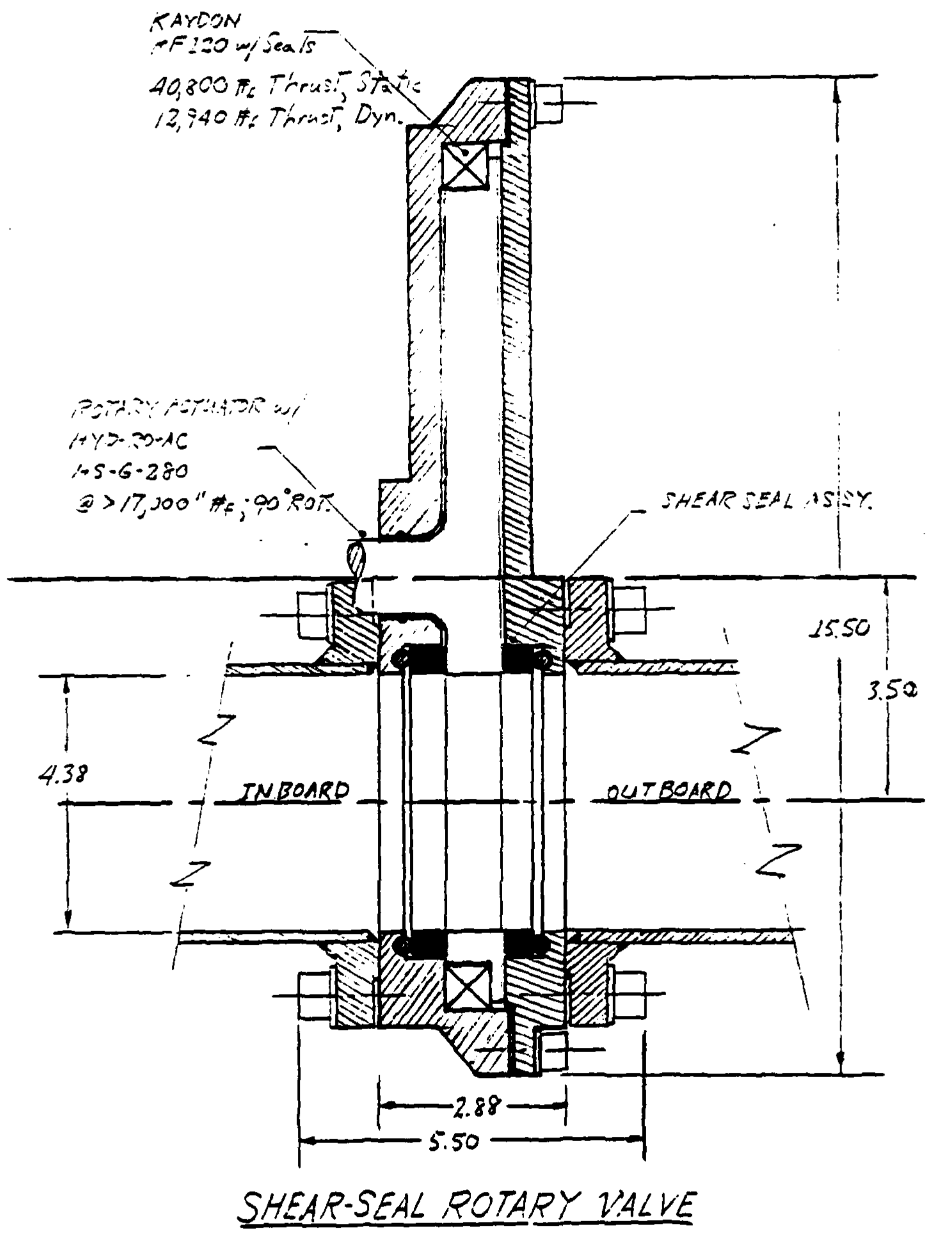


Figure 3.2.1.5.1(d). Shear-Seal Rotary Valve Concept (Sheet 1)

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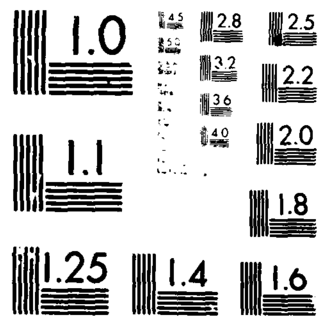

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

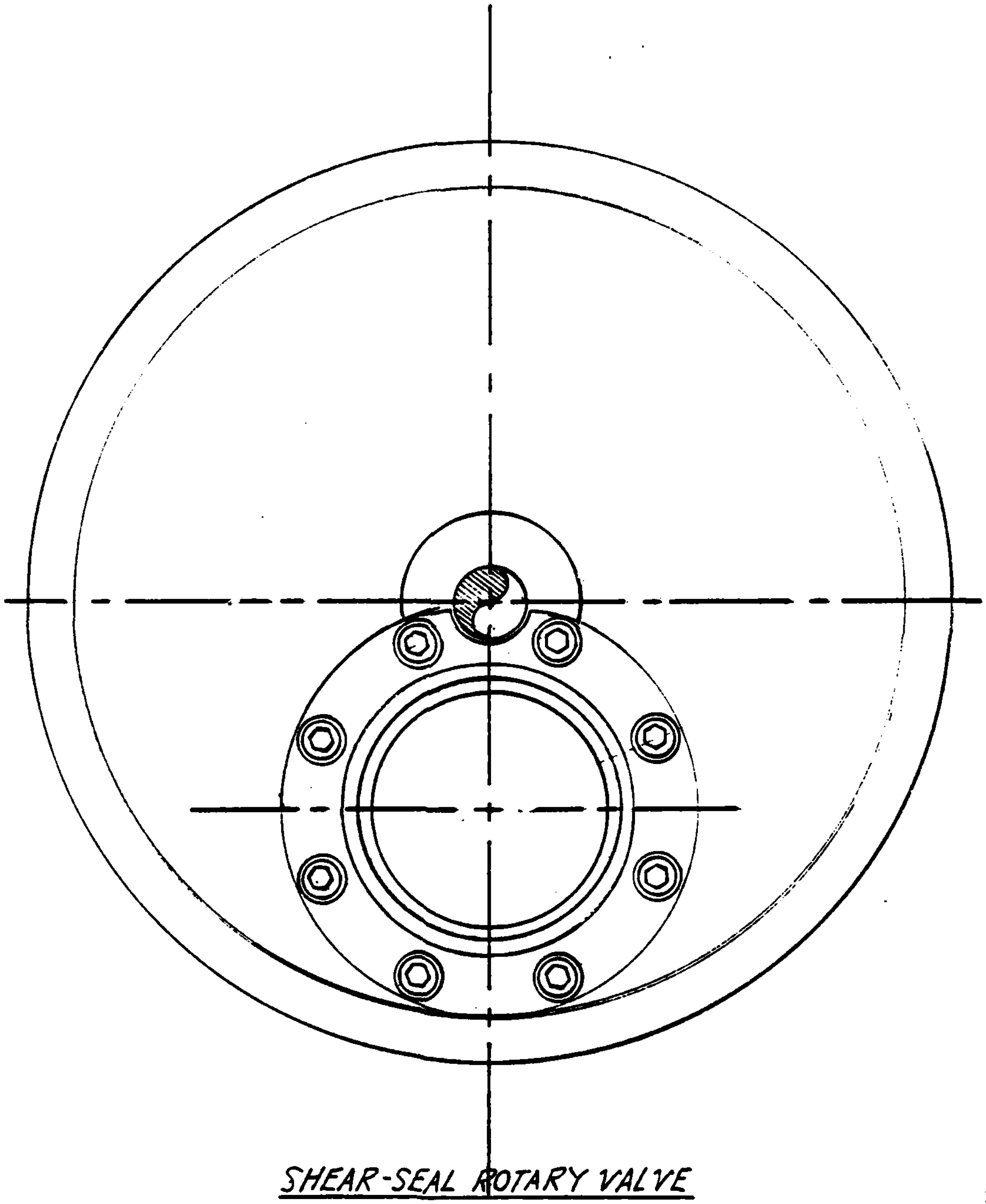

Figure 3.2.1.5.1(d). Shear-Seal Rotary Valve Concept (Sheet 2)

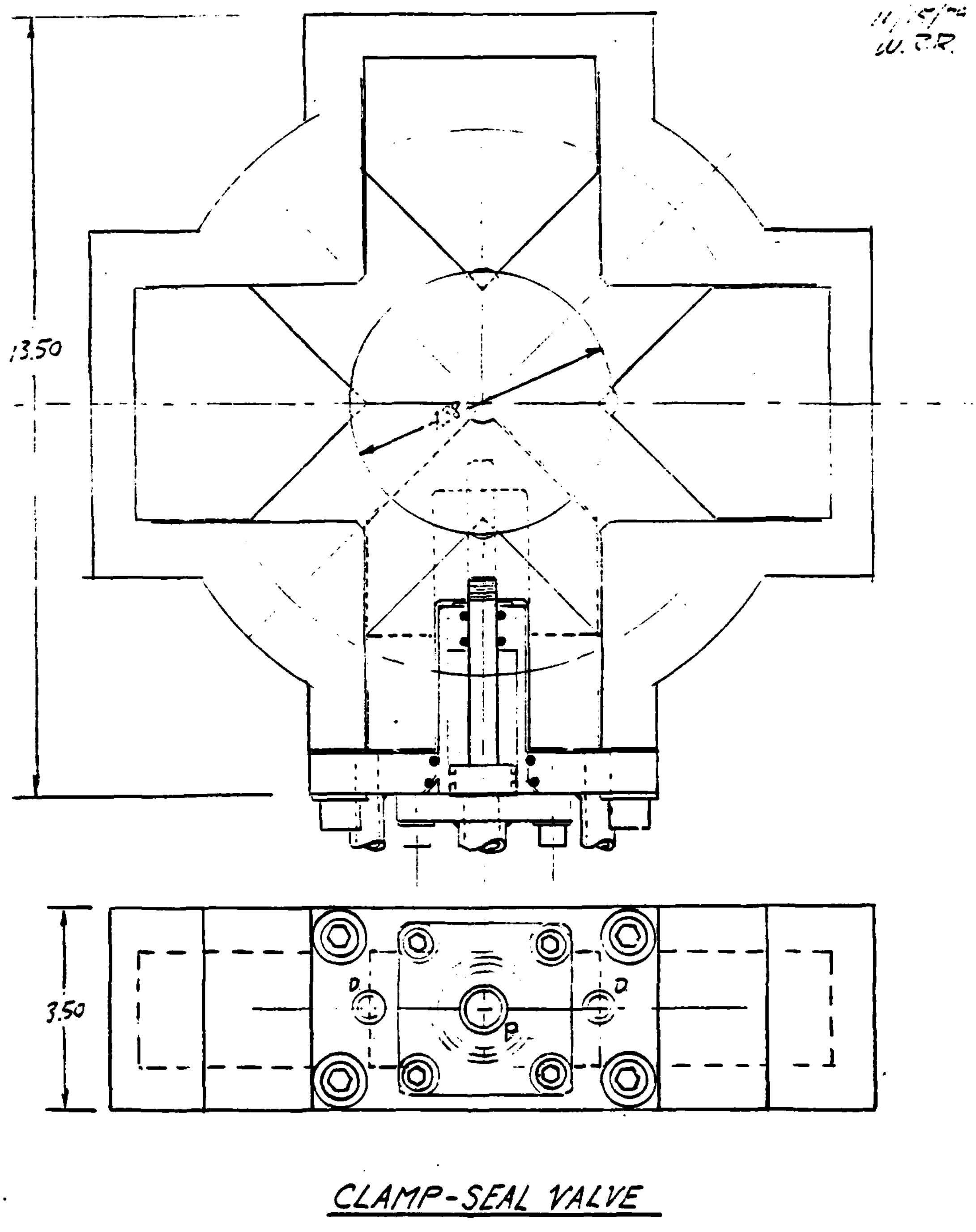

Figure 3.2.1.5.1(e). Clamp-Seal Valve Concept

(3)	Sensors:	Must interface with valve position sensors with the Buoyant Cable Assembly interface sensors, and all associated seals etc., to coordinate operation of the valves during passage of the cable end termination thru the Conduit/Guide Tube. Must also respond to either cable loss, or severing command.
(4)	Seals:	Sequencing will be required with the seals during passage of the cable end termination to assure that SUBSAFE integrity of the pressure hull is maintained.
(5)	Power Source:	Actuation power, either electric or hydraulic. Note that manual override will also be required. Additionally, alternate power sources may be required to assure redundant, positive action of the failsafe shutoff valve and perhaps the hull valve.

3.2.1.5.4 Pros & Cons Summary

Hull Valve & Fail-Safe Shutoff Valve	Pro	Con
• Ball Valve (Miser Titanium Series 49)	• Simple/Reliable • Commercial Available	• 6.77 in. Face-to-Face • Extremely expensive @ \$9,700 for 6" size (4.37 in. bore)
• Rotary Shear-Seal Valve (Monel 400)	• Simple construction • Sound Operating principle • Est. @ \$5,000 cost • 3.0 ± .12 in. Face-to-Face	• New concept (only in flow thru) vs. 90 or 180° Barksdale Shear-Seal Valve.

• Clamp-Seal Valve (Monel 400) either 2 or 4 clamp	• Simple construction • Sound operating principle • Est. @≈$5,000 cost • 3.5 ± .12 in. Face-to-Face • Could operate potentially as a manual static seal with proper resilient ram tip configuration.	• Requires gravity drain to assure zero leakage.
• Single Blade Ram	• Can Shear a 1.1 in GIPEX armored cable, 90,000$\#_f$ test with 3 in. bore hyd. cyl. w/3000 psi. Cutting blade & Ram Stop plate details per AN/SQR-19 design.	-

3.2.2 DISCUSSION

3.2.2.1 Characterization of the Valves

During the current study effort, we have shown that viable alternatives exist for assuring that both the hull valve and the Failsafe Shutoff Valve can be selected from the options proposed in 1.1.5.1. Additional research is suggested in order to fully define the tradeoff alternatives, make detailed analysis and resolve the available options to a single recommendation. Development of an acceptable valve configuration is considered to be a high risk engineering effort. Further definition is suggested.

The Cable/Antenna Element shear assembly capable of shearing the buoyant cable and/or a 4 in. OD antenna element is considered to be a medium risk engineering effort.

3.2.2.2 Analysis of Considerations

The hull valve, cable/antenna element shear assembly and the failsafe shutoff valve are all located outboard of the dynamic seal. This consequently reduces the susceptibility of the buoyant cable assembly to buckling. However, the inboard failsafe shutoff valve, if required in the configuration, is critical vis-a-vis face-to-face dimensional impact on cable unsupported length, and consequent buckling.

Conventional, commercially available valving cannot provide a reasonable face-to-face dimension for a 6 in. O.D. antenna element capacity.

3.2.2.3 Recommendations

Further definition, analysis is recommended. The Miser Titanium Series 49, 6 in. size is currently considered to be an acceptable choice for the DRSS, and would meet all SOW requirements. However, the two new concept alternatives proposed could offer significant advantages with respect to enhanced Buoyant Cable Assembly performance at greater submergence depths. These alternative concepts should also cost less.

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VOLUME II, SECTION 3, PART 3 - SEALS STUDY

PART 3

SEALS STUDY

3.3.1 INTRODUCTION

3.3.1.1 Definition

A seal is defined by the establishment of an effective leakproof interface between the ship's pressure hull and the Buoyant Cable Assembly; and shall be located inboard of the Failsafe Shutoff Valve. Refer to Figure 3.1.1.1.*

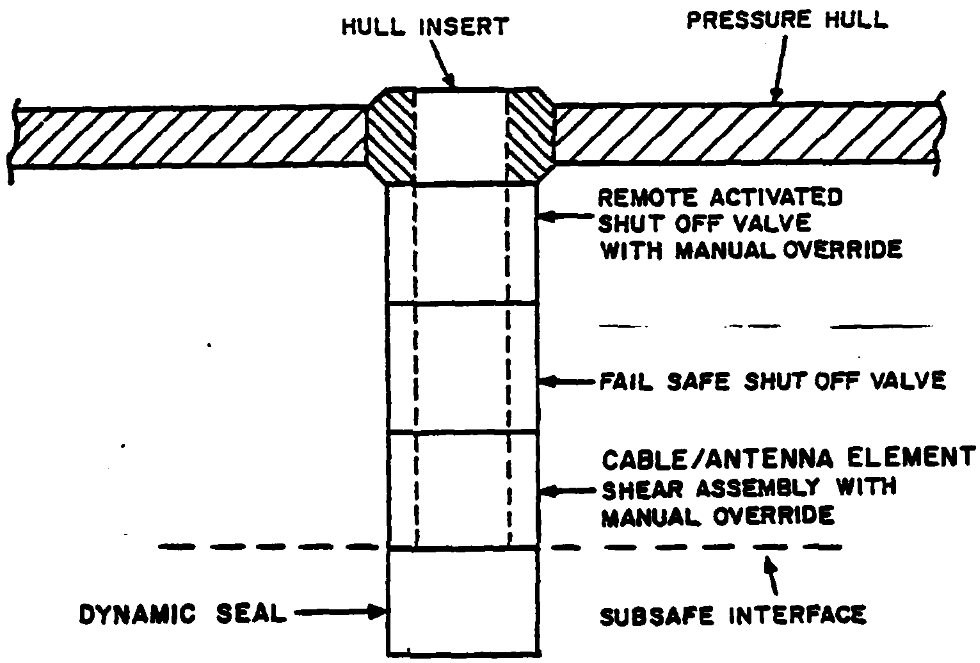

Figure 3.3.1.1.1

*A detailed description and discussion of the configuration depicted is found in Section 3, Part 2, Valves Study.

A leakproof interface shall be defined as follows:

- Static Seal - less than 5 in.^{3}/Hr @ 600 PSID.
- Dynamic Seal - less than 12 in.^{3}/Min @ 600 PSID, .003 annulus.

In both cases, the ship's gravity drain system is be employed to remove seawater from within the seal mechanism envelope, to achieve a net zero leakage through the pressure hull.

3.3.1.2 Problem Areas

The state-of-the-art of static and dynamic seals must be advanced to provide reliable equipment that will pass antenna elements up to six inches in diameter. This is true for both static and dynamic seals. This problem is further complicated by the requirement to seal against full submergence depth and at line speeds of 200 feet per minute to 400 feet per minute without damage to the cable/antenna.

- Static Seal for Steady State Towing

  This seal must operate against the cable without (0.65 inches and/or 0.5 to 1.0 inches diameter) and at zero line speed. It must be capable of opening its bore to pass the full diameter of the antenna elements which may be up to 6.0 inches. Since this seal must have zero leakage. It must restrain the submergence pressure from pushing the cable into the submarine. This restraining force is the cable cross section area times the depth pressure minus the hydrodynamic drag. The seal must not damage nor deform the cable during use and must not contribute to cable buckling.

- Dynamic Seal for Fixed Diameter Cable

  One of the system concepts generated in this study requires a dynamic seal to be used to seal against the small diameter cable (0.65 inches). This diameter will be a fixed constant over the portion of the cable/antenna where sealing is required. In order to pass the large antenna elements, the seal must be capable of opening its bore to the full diameter of the antenna elements. Sealing is not required during this operation. This seal must create a very low friction drag force (approaching zero) on the cable to achieve a line speed of 200 to 400 feet per minute. The allowed volume of seawater leakage through the seal depends on the system configuration. The seal must function at all submarine operating depths and must not damage or degrade the cable during use, and must not contribute to cable buckling.

- Dynamic Seal for Variable Diameter Cable/Antenna

Two system concepts utilizes dynamic seals which can automatically increase their small cable sealing diameter to accommodate the larger diameter antenna elements. These devices must operate automatically and maintain their sealing integrity at maximum submergence pressure and cable/antenna line speeds of 200 to 400 feet per minute, they must not contribute to cable buckling.

Some friction can be allowed in the sealing mechanism and some seawater leakage may also be tolerated depending on the system configuration. However, the seals must not exert more than 100 lbs/foot shear force on existing antennas (approximately 8.8 lbs per square inch of cable surface area).

In order to achieve capability to deploy the Buoyant Cable Assembly, .65, 4.0 or 6.0 inch diameter -- and/or a .50 $\rightarrow$ 1.00 inch diameter -- against submergence pressures, it will be necessary to consider means to equalize the pressure differential against changes in cross-sectional area as it passes thru the outboard seal. Otherwise, unacceptable cable buckling forces (for diameters greater than 0.65 inch) would be sustained. Current design capability is $80\#_f$ for the existing cable @ 6.5 inch unsupported length. A Staging Tube is mandatory in order to permit the minimum antenna element diameter of 4.0 inch O.D. to pass through the outboard seal. This force could exceed the design Requirement of $3000\#_f$ dynamic load and design Goal of $6000\#_f$ dynamic load capability of the DRSS study effort.

3.3.1.3 Requirements

3.3.1.3.1 The allocated Requirements and Goals to the Deploy/Retrieve Mechanism are as shown in Figure 3.3.1.3.1. Additional CID evaluation criteria which were employed are:

a. No. of Components - determine relative complexity.

b. Inherent Reliability - determine a characteristic MTBF.

c. Development Cost - determine relative budgetary cost estimate to produce a working prototype (including drawings).

d. Cable Contact Efficiency - characterized determination of cable handling method, and the consequent potential degree of impact on the cable structure geometry.

e. Friction Dependence - evaluation of the susceptibility of performance degradation based on environmental friction characteristics variability vs a minimum μ required by the particular mechanism to transmit energy into the cable assembly system.

f. Fatigue/Wear Impact - characterized determination of the cable handling method, and the consequent impact on cable structure failure.

g. Producibility - relative estimate of degree of difficulty in fabrication/assembly and qualification test of the particular mechanism analyzed.

3.3.1.3.2 All allocated Rquirements/Goals and CID evaluation criteria are employed to determine the relative ranking of the component configurations analyzed, in Tradeoff Summary Chart(s), Figures 3.3.2(a) and 3.3.2(b).

3.3.1.4 Analytical Approach

3.3.1.4.1 Each candidate component configuration is analyzed/characterized, to the extent necessary, to support the generation of numerical values which can be employed in the tradeoff summary charts for assessment of the degree to which each evaluation

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DRSS SOW REQUIREMENTS/GOALS
ALLOCATION TO COMPONENT LEVEL

COMPONENT	REQUIREMENTS	GOALS
• TOW/EXIT POINT	4, 5, 6, 10, 11, 13, 14, 15, 16	1,2,3
• CABLE GUIDE -		
- CONDUIT	4, 5, 6, 9, 10, 11, 13, 15, 16	
- SEALS	1, 2, 3, 4, 5, 6, 10, 11, 14, 18	1
- CABLE/ANTENNA ELEMENT SHEAR DEVICE	1, 2, 4, 6, 9, 10, 11, 14, 20	
• DEPLOY/RETRIEVE MECHANISM	3, 4, 5, 6, 8, 9, 10, 11, 13, 14, 15, 16, 18, 20	1,2,3,5
• STORAGE ASSEMBLY	1, 3, 5, 6, 8, 9, 10, 11, 12, 13, 15, 16, 20	1,2,3,5
• SENSORS	1, 4, 5, 6, 9, 10, 11, 12, 14, 15, 16, 17	1,2,3,4
• CONTROLS	3, 6; 15, 17, 18, 20	2,3,4,5
• POWER SOURCE	3, 6, 8, 15, 16, 20	2,3
• ANTENNA/RF INTERFACE	1, 2, 4, 5, 9, 10, 11, 12, 13, 14, 15, 16, 17	2,3,4

NOTE: (1) REQUIREMENTS #7 & 19 ARE APPLICABLE TO ALL OF THE ABOVE.

Figure 3.3.1.3.1. DRSS SOW Requirements/Goals Allocation to Component Level

criteria can be met. A separate Appendix (N thru S) provides the basis for all characterizations made for the particular component analyzed. An *evaluation criteria* analysis, Section 5, provides a brief summary description of the methodology employed in generating the numerical assessment values presented in the Tradeoff Summary Chart Figure 3.3.2(a). Data presented in this chart is normalized and weighted in order to establish the relative ranking of each of the candidates, and is shown in Tradeoff Summary Chart Figure 3.3.2(b). A Ranking Summary, Analysis of Results and Recommendations are made in paragraphs 1.2.2, 1.2.3, and 1.2.4, respectively based upon the data presented in Figure 3.3.2(b).

3.3.1.5 Candidates

3.3.1.5.1 A review of the present BRA-24 and BRA-18 buoyant cable antenna handling system capabilities, problem areas, analysis of the SOW Requirements and Goals and comparison to existing technology/hardware adaptable to application as a dynamic seal, has resulted in the selection of four possible candidates. They are as follows:

Candidate	Closest Analogy/ Similarity	Refer to Analysis
• Dyn. Seal Var. Articulated Seg.	-	Appendix P
• Dyn. Seal, Var., Bladder	BRA-18, 24 & CID Proposal	Appendix Q
• Dyn. Seal, Fixed, Two-Posn., Split	CID Proposal	Appendix R
• Dyn. Seal, Var., Iris	-	Appendix S
• Static Seal	Fixed, 2-Posn., Split Dyn. Seal Concept	Appendix R

3.3.1.5.2 Each candidate operates on an entirely different principle, with characteristics unique to the cable sealing technique employed. The configurations depicted are idealized concepts, which establish the basis for analytical characterizations in their respective Appendixes P → S — and supported by Appendices N and O. Each appendix includes a concept configuration, layout, description, operating exploration, considerations made in the analysis, and, where required references to other Appendices which support the study effort characterizations.

3.3.1.5.3 The Seal mechanisms interface with the following:

- Valving
- Conduit/Guide Tube
- Controls
- Sensors
- Power Source

Interface Requirements Discussion

(1) Valving — Must interface with associated, immediately adjacent valving, i.e. -

- At the Subsafe Interface to the Cable/Antenna Element Shear Assembly. . .
- At the Staging Tube Interface, to the Seawater Vent/Fill Valve . . .
- At the Inboard portion of the Staging Tube, to the Failsafe Shutoff Valve.

(2) Conduit/Guide Tube — Must maintain structural integrity and leaktight boundary equal to that of the pressure hull.

(3) Controls — Must interface with the Control/Indicational Panel for actuation and status condition.

(4) Sensors — Must interface with the Buoyant Cable Assembly interface sensors, and all associated valving status sensors, to coordinate operation of the seals during passage of the antenna elements through the staging tube.

(5) Power Source — Actuation power, either electric or hydraulic. Note also that a Manual Override may be required.

3.3.1.5.4 Pros & Cons Summary

Mechanism	Pro	Con
• Dyn. Seal, Var., Articulated Seg.	• Variable dia. @ .50 → 1.00 or .65 → 1.38 in. • Very low leakage	• Complex-low reliability • Cannot accommodate > 2:1 ratio in cable diameter
• Dyn. Seal, Var., Bladder	• Simple • Variable dia. @ .50 → 1.00 or .65 → 1.38 in. • Zero leakage	• Cannot accommodate > 2:1 ratio in cable diameter
• Dyn. Seal, Fixed, Two-Posn., Split	• Simple • Seals either .50 or .65 in. diameter cable -- opens to > 4.0 inch • Very low leakage • Meets all Requirements and Goals	• Cannot accommodate continuously variable dia. cable
• Dyn. Seal, Var., Iris	• Seals all diameter cables, incl. continuously variable	• Complex-low reliability • Med to High leakage • Large envelope reqd.
• Static Seal, 2-Posn., Split (alt. is a 4-Posn., Split --	• Can achieve zero leakage • Simple • Accommodates .50 OR .65 in. B.C.A.	-

3.3.2 DISCUSSION

3.3.2.1 Tradeoff Summary Chart(s) Figure 3.3.2(a) and 3.3.2(b) Explanation

The first Chart Figure 3.3.2(a) depicts the values derived in the Evaluation Criteria Analysis. The second Chart Figure 3.3.2(b) depicts the final numerical summary, with values generated as follows:

(a) Select optimum value in each of the successive columns.

(b) Normalize all other values in that column against the optimum value.

(c) Apply the appropriate weighting factor, i.e., CID evaluation criteria @ Base; Requirements @ 2X Base; and Goal @ 3X Base.

(d) Sum and horizontal rows to generate the intermediate Subtotal and the final Grand Total.

3.3.2.2 Ranking Summary

(a) Mean Value = 28.04; Standard Deviation = 1.60

(b) Ranking according to highest value -- with significant difference equal to 1 Standard Deviation from the maximum Ranking Values:

Dyn. Seal, Fixed, Two-Posn; Split	-	1st @ 30.74
Dyn. Seal, Var., Articulated Seg.	-	2nd @ 28.31
Dyn. Seal, Var., Iris	-	2nd @ 27.33
Dyn. Seal, Var., Bladder	-	3rd @ 25.78

3.3.2.3 Analysis of Results

(a) Although a significant advantage appears for selection of the Fixed Two Position Split type of dynamic seal direct application of such a configuration would be very difficult in meeting the G1 goal of .50 → 1.00 diameter. A continuously varying cable diameter would necessitate a variable acticulation adaption, whereas antenna elements going from .50 → 1.00 in. could be

Allocated Evaluation Criteria			Variable-Artic. Seg.	Variable-Bladder	Fixed-2 Posn., Split	Variable Iris
			Seals Configurations			
SOW Requirements						
R1		Positive Seal Sealing	.003	.075	.003	.06
R2		Shear Seal Capability	N/A	N/A	N/A	N/A
R3		Airborne Noise/Structureborne Noise	1	3	3	2
R4		Dynamic Load Capability, Δ PSI	180	180	180	180
R4		Static Load Capability, Δ PSI	1000	1000	1000	1000
R5		Imposed Shear Stress/Tensile Stress	4.08	4.08 8.16	4.08	4.08
R6		Installation Compatibility	1	3	3	2
R7		Envelope, Ft^3	.5	.5	.5	.75
R8		Maintainability/Accessibility	1	3	2	1
R9	11&14	Cable Size	.65 1.38	.60 1.38	.65 4.0	.65 4.0
R15		FPM Capability	200	200	200	200
R19		Weight, $\#_f$	100	100	100	100
SOW Goals						
G1		Variable Diameter .50 → 1.0 in.	X	X	-	X
G2		400 FPM Capability	X	-	X	X
		SUBTOTAL				
CID Evaluation Criteria						
-		No. of Components	45	6	8	81
-		Inherent Reliability, MTBF	1203	761	3185	822
-		Developmental Cost X 1000 $	112	36	261	80
-		Cable Connect Effeciency	93	100	100	90
-		μ Dependence	3	1	3	3
-		Fatigue/Wear Impact	3	1	3	2
-		Producibility	3	5	9	4
-		Level I Mat'l Control Traceability System	X	X	X	X
		GRAND TOTAL				

Figure 3.3.2(a). Seals Configurations Tradeoff Summary Chart

Allocated Evaluation Criteria			Seals Configurations: Variable-Artic. Seg.	Variable-Bladder	Fixed-2 Posn., Split	Variable Iris
SOW Requirements						
R1		Positive Seal Sealing	2	.08	2	.1
R2		Shear Seal Capability	-	-	-	-
R3		Airborne Noise/Structureborne Noise	.33	.66	1	.33
R4		Dynamic Load Capability, Δ PSI	2	2	2	2
R4		Static Load Capability, Δ PSI	2	2	2	2
R5		Imposed Shear Stress/Tensile Stress	2	1	2	2
R6		Installation Compatibility	.66	2	.66	1.33
R7		Envelope, Ft^3	2	2	2	1.33
R8		Maintainability/Accessibility	.66	2	1.33	.66
R9	11&14	Cable Size	.69	.69	2	2
R15		FPM Capability	2	2	2	2
R19		Weight, $\#_f$	2	2	2	2
SOW Goals						
G1		Variable Diameter .50 → 1.0 in.	3	3	-	3
G2		400 FPM Capability	3	-	3	3
		SUBTOTAL	22.31	22.78	27.74	21.33
CID Evaluation Criteria						
-		No. of Components	.13	1	.75	.07
-		Inherent Reliability, MTBF	.38	.24	1	.26
-		Developmental Cost X 1000 $	.18	.56	1	.25
-		Cable Connect Effeciency	.95	1	1	.9
-		μ Dependence	1	.33	1	1
-		Fatigue/Wear Impact	1	.33	1	.66
-		Producibility	.33	.56	1	.44
-		Level I Mat'l Control Traceability System	.2	2	2	2
		GRAND TOTAL	28.31	25.78	30.74	27.33

Figure 3.3.2(b). Seals Configurations Tradeoff Summary Chart

accommodated. In order to meet both the R9 → 11, R14 size capability <u>and</u> the G1 requirement, two staged seal assemblies, i.e., in tandem, would have to be installed, with the assumption that the .50 → 1.00 G1 criteria implies antenna elements.

A key development consideration must be the characterization of the viscous fluid for sealing vs temperature and pressure differentials — and what happens to the fluid when the split seal opens up. (Up to .75 $in.^3$ fluid could be lost with each opening.) An optional consideration could be to incorporate a drain circuit between wipers in the seal assembly and/or eliminate the viscous fluid entirely.

(b) The Variable, Articulated Segment type is too complex and limits Antenna Element Size Capability to 1.38 in. OD.

(c) The Variable Iris type is felt to be limited in capability to minimize leakage and is extremely complex. However, it does appear capable of handling all cable sizes from .50 → 4.00 in.

(d) The Variable Bladder type is limited to a 2:1 expansion ratio limitation (maximum) due to inherent material elastic properties limitations. If some means could be developed to permit higher expansion ratios up to 6.15:1 with a bladder material that can withstand a 600 psi operational pressure difference without integral material reinforcement, then this type would become preferential in selection over (b) and (c) — and perhaps (a).

3.3.2.4 Recommendations

Select the Fixed Two Position Split type of dynamic seal as the primary candidate offering the best possibility of meeting the Requirements/Goals with the least development risk and highest cost effectiveness.

SECTION

TABLE OF CONTENTS

VOLUME II, SECTION 4, TOW/EXIT POINT STUDY

SECTION 4

TOW/EXIT POINT STUDY

4.1 INTRODUCTION

4.1.1 Defintion

4.1.1.1 The Tow point is the point outboard of the pressure hull at which the antenna assembly exits the superstructure of the submarine.

4.1.1.2 The concept(s) shall optimize the tow/exit point location, shape and size to obtain maximum speed/depth performance from the antenna system; and sustain the loading imposed by high speed/long cable length towing. The tow/exit point shall not impose constraints, or excessive loading on the cable, and in-line components of present and future antenna assemblies.

4.1.2 Problem Areas

4.1.2.1 The configuration requirements imposed direct possible solution(s) toward a bellmouth having a contour radius greater than 12 inches, with arc-of-contact of 90°. The bellmouth must sustain a 6000# to 10,000# tow load at 90° flight angle under high speed/long cable length deployment, retrieval or streaming operation -- with the submarine in a sharp turn. The concept configuration objective must be directed towards a means by which this can be achieved, yet minimize both structural impact and the hydrodynamic drag profile.

4.1.2.2 The tow point must be located to allow the cable/antenna assembly to clear the vertical rudder, horizontal stabilizers, and propeller. This could be accomplished by locating the tow point on the horizontal stabilizers. However, at this location it would interfere with existing STASS and TB-16 towed array tow points and the future CHETSA tow point. The top of the rudder is an acceptable location. However it is hard to implement mechanically. If the tow point is located at the top most aft position of the sail, the cable/antenna assembly will clear the rudder and stabilizer. Also, the depth at which the submarine can operate while communicating will be enhanced.

4.1.2.3 Corrosion/Fouling must be addressed vis-a-vis material selection.

4.1.3 Requirements

4.1.3.1 The allocated Requirements and Goals to the Tow/Exit Point are as shown in Figure 4.1.3.1. Refer to the Discussion paragraph 4.2 for analysis and recommendation. Additional CID evaluation criteria which were employed are:

a. No. of Components - determine relative complexity.

b. Inherent Reliability - determine a characteristic MTBF.

c. Development Cost - determine relative budgetary cost estimate to produce a working prototype, (including drawings).

d. Cable Contact Efficiency - characterized determination of cable handling method, and the consequent potential degree of impact on the cable structure geometry.

e. Friction Dependence - evaluation of the susceptibility of performance degradation based on environmental friction characteristics variability vs a minimum μ required by the particular mechanism to transmit energy into the cable assembly system.

f. Fatigue/Wear Impact - characterized determination of the cable handling method, and the consequent impact on cable structure failure.

g. Producibility - relative estimate of degree of difficulty in fabrication/assembly and qualification test of the particular mechanism analyzed.

4.1.3.2 The Evaluation Criteria are employed to ascertain whether the proposed concept configuration is capable of meeting the Requirements and goals and CID evaluation criteria. Refer to Section 5 for Analysis.

4.1.4 Analytical Approach

4.1.4.1 The candidate concept configuration is analyzed/characterized to the extent necessary in the Discussion paragraph 4.2, to assess whether or not each of the allocated Requirements and Goals can be met. Additional CID evaluation criteria are imposed to

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DRSS SOW REQUIREMENTS/GOALS
ALLOCATION TO COMPONENT LEVEL

COMPONENT	REQUIREMENTS	GOALS
• TOW/EXIT POINT	4, 5, 6, 10, 11, 13, 14, 15, 16	1,2,3
• CABLE GUIDE -		
- CONDUIT	4, 5, 6, 9, 10, 11, 13, 15, 16	
- SEALS & VALVES	1, 2, 3, 4, 5, 6, 10, 11, 14, 18	1
- CABLE/ANTENNA ELEMENT SHEAR DEVICE	1, 2, 4, 6, 9, 10, 11, 14, 20	
• DEPLOY/RETRIEVE MECHANISM	3, 4, 5, 6, 8, 9, 10, 11, 13, 14, 15, 16, 18, 20	1,2,3,5
• STORAGE ASSEMBLY	1, 3, 5, 6, 8, 9, 10, 11, 12, 13, 15, 16, 20	1,2,3,5
• SENSORS	1, 4, 5, 6, 9, 10, 11, 12, 14, 15, 16, 17	1,2,3,4
• CONTROLS	3, 6, 15, 17, 18, 20	2,3,4,5
• POWER SOURCE	3, 6, 8, 15, 16, 20	2,3
• ANTENNA/RF INTERFACE	1, 2, 4, 5, 9, 10, 11, 12, 13, 14, 15, 16, 17	2,3,4

NOTE: (1) REQUIREMENTS #7 & 19 ARE APPLICABLE TO ALL OF THE ABOVE.

Figure 4.1.3.1. DRSS SOW Requirements/Goals Allocation to Component Level

ascertain: (1) factors impacting on engineering or manufacturing feasibility and (2) unit production cost factors which will be used as the basis of Design to Cost evaluation at the Systems Level in Volume I. Finally, a Recommendation is made based upon the results of the evaluations.

4.1.5 Candidate

4.1.5.1 The candidate approach selected for evaluation is an articulated bellmouth, per Concept Configuration Figure 4.1.5.1. A detailed configuration description, operating explanation and consideration(s) overview is presented in the Discussion paragraph 4.2.

4.1.5.2 The Tow/Exit Point interfaces with the following:

- Conduit/Guide Tube: Rigid joint not possible, articulation clearance of > 1/4 in. recommended.
- Submarine Superstructure: Minimize envelope requirements such that installation feasibility is possible for both potential locations. Minimize hydrodynamic drag profile impact.

4.1.5.3 Pros and Cons Summary

Mechanism	Pro	Con
• Articulated bellmouth Tow/Exit Point	• Envelope $< .84\ ft^3$ • Wt $< 150\#_m$ • 90^o bend capability • Bellmouth entrance/exit max. cross-sectional area $< 64\ in.^2$	Imposed shear load approx. $379\#_f$/linear ft for 0.65 Dia cable and 12 in. contour radius

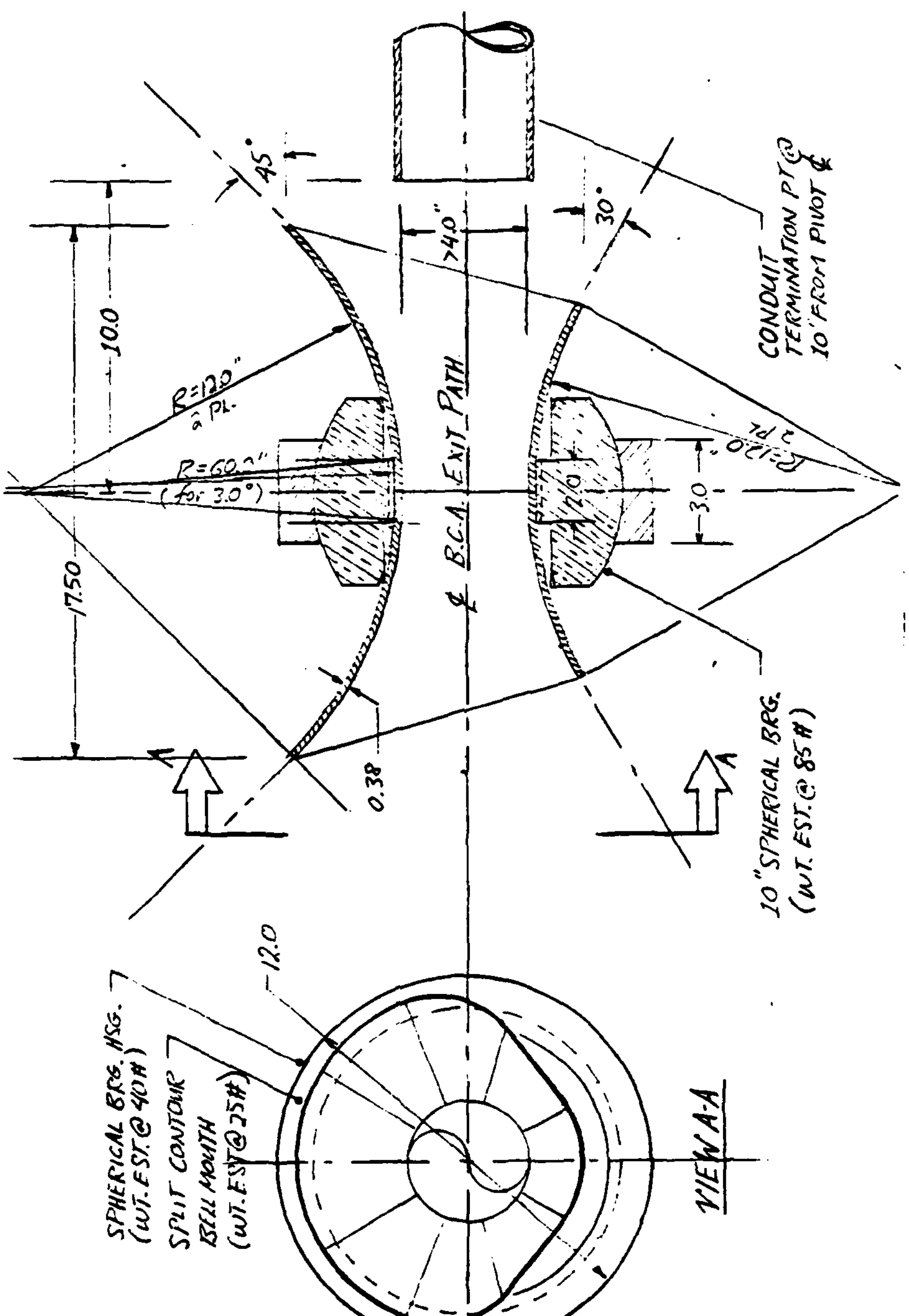


Figure 4.1.5.1. Articulated Bellmouth, Tow/Exit Point

4.2 DISCUSSION

4.2.1 Characterization of the Tow/Exit Point

- **Configuration:** Sized to accept 4 in. OD x 4' long antenna elements, the bellmouth is required to accept $\approx 90^\circ$ of bend concentric to the ship longitudinal centerline -- constrained that hull superstructure boundaries including aft horizontal and vertical stabilizers do not intercept the free streaming B.C.A. under maneuvering conditions. Assume static guide surfaces.

  As a conventional bellmouth permitting 90° of bend accommodation would require an exit opening approximately 28 inches across, an articulated bellmouth, having a 12 inch max width is analyzed. Refer to Figure 4.1.5.1. This will provide the minimum impact on installation envelope requirements, hydrodynamic drag profile, and system weight.

- **Operation:** The bellmouth is passively reactive to outboard force imbalance (beyond the spherical ball joint pivot point —and is forced to align itself to minimize this imbalance. Maximum accommodation is a 45° pivot plus that of the exit bellmouth fairing of 45° -- or 90°. Bellmouth articulation commenses at a flight angle $> 5^\circ$; with a 2.50 F.S. @ 30° -- assuming $\mu_{ball} \leq .05$, cable tension = $6000\#_f$ and $\mu_{bellmouth} \leq .50$.

- **Interfaces:**
  (1) Option 1 -- Sail Superstructure and Conduit
  (2) Option 2 -- Aft Vertical Stabilizer and Conduit

- Considerations:
  - (a) Materials Selection
  - (b) Structural Requirements
  - (c) Loading imposed on the B.C.A.
  - (d) Location
  - (e) Heat Transfer

4.2.2 Analysis of Considerations

(a) Materials selection, re corrosion resistance, is limited to the material options listed in Section 3, Part 1 — with Monel 400 (or equivalent) recommended. Due to the conic bellmouth geometry required for the Tow/Exit Point, a cast structure is indicated -- with material - Monel - per QQN-288, $\sigma_y = 32{,}000 \rightarrow 80{,}000$ psi.

(b) Structural Requirements are based upon determination of the operating profile for Retrieval/Deployment and tan θ, array elevation vs scope @ varying speeds up to $3000\#_f$ minimum requirement and $6000\#_f$, goal. (Refer to Appendix H.)

(1) At 5 knots, 420.9' elev./4992 ft scope = $186.6\#_f$; $\theta = 4.84^\circ$

(2) At 7.5 knots, 274.5' elev./4992 ft scope = $397.2\#_f$; $\theta = 3.15^\circ$

(3) At 10 knots, 201.3' elev./4992 ft scope = $696.3\#_f$; $\theta = 2.31^\circ$

(4) At 15 knots, 128.2' elev./4992 ft scope = $1555.5\#_f$; $\theta = 1.47^\circ$

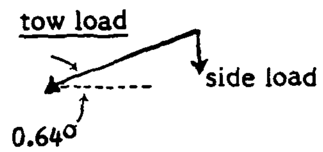
(5) At 20 knots, 91.9' elev./4992 ft scope = $2760.4\#_f$; $\theta = 1.06^\circ$

The static tow load requirement is $6000\#_f$ minimum and $10{,}000\#_f$ goal.

(c) Calculation of Loading, imposed on the B.C.A. is made for two cases: (1) Point Contact or Side Loading due to towing and (2) Imposed Shear Load during Retrieval/Deployment operations.

(1) i Per Appendix H, the minimum Requirement 13 for a static tow load of 6000$\#_f$. At this load and 5000 ft of scope, an elevation of 55.6 ft yields a rise angle of 0.64° and a load of 6205.2$\#_f$.

ii By a vector approximation, to find the imposed side load,



$\sin 0.64^\circ$ = side load/tow load

0.01118 x 6205.2$\#_f$ = side load =; = 69.37$\#_f$

iii As $\approx 3^\circ$ included angle is incorporated at the bellmouth throat, thru an arc-of-contact of 2 in., the 69.37$\#_f$ is distributed over $.53^\circ/3^\circ$ x 2 in. or .353 linear inches by approx. 0.25 in. cable contact width; or .088 in.^{2}.

Point Contact Loading, psi = 69.37$\#_f$/.088 in.^{2}

= 785.3 psi

Distributed loading would occur over an arc-of-contact of 18.85 in. for a submarine at high speed in a sharp turn; or P.C.L. = 5.20 psi !

This is acceptable.

(2) i Per Requirement 16, the minimum dynamic loading is 3000$\#_f$. This load is found at approximately 20 knots speed, 5000 ft of scope, where an elevation of 91.9 ft yields a rise angle of 1.06° and a load of 2760.4$\#_f$.

ii By the Euler Relation, the distributed load across a bend angle of 1.06° is found as follows:

$$T_i/T_o = e^{\mu\alpha}$$

where $T_o = 2760.4\#_f \approx 3000\#_f$

$\mu = .40$

& $\alpha = 1.06^o \times 2$

$\therefore \quad T_i = T_o \times 1.00743$

$= 3022.3\#_f$

$\therefore$ The distributed load is $22.3\#_f$

iii As the arc-of-contact equals $1.06^o/3^o \times 2"$, or .707 inches the imposed shear load is:

Shear load, per linear ft = $(22.3\#_f/.707 \text{ in.}) \times 12 \text{ in./ft}$

$= \underline{378.7\#_f\text{/linear ft}}$

iiii Per Appendix G, the allowable shear loading equals $733\#_f$/linear ft. Therefore the above value in iii is acceptable.

(d) There are two desirable locations for the Tow/Exit Point: (1) the topmost, aft point of the sail superstructure and (2) the topmost, leading edge of the vertical stabilizer. System Concept A, B, C and D uses location (1) and System Concept E uses location (2). Location (1) is recommended since it provides the maximum possible submerged running depth. Space requirements for the articulated bellmouth are < .84 ft^3 ($\approx$10 in. cylinder x 17.5 inches long). Consequently the Hydrodynamic drag profile upset is minimized.

(e) Heat transfer requirements impose minimal constraints upon the design. Refer to Section 3, Part 1, paragraph (j) for analysis.

4.2.3 Recommendation

Employ the candidate concept configuration as defined since all evaluation criteria (per paragraph 4.3.1), and considerations appear to be met.

SECTION 6

SECTION 5

EVALUATION CRITERIA ANALYSIS

TABLE OF CONTENTS

INTRODUCTION

The evaluation criteria analysis (ECA) provides a summary of the methodology employed in generating the numerical ratings presented in the tradeoff summary charts. The ECA includes some of the assumptions used in the analysis so that a better understanding of the assessment may be obtained. The detailed calculations to back up the ECA are contained in the appendices and are referenced where appropriate.

Three kinds of evaluation criteria were used in the study. The first two are SOW requirements and goals. The third is the CID evaluation criteria. The CID evaluation criteria were employed because these additional engineering considerations were considered necessary by CID to help discriminate among the many candidates in each tradeoff analysis.

5.1 DEPLOY/RETRIEVE MECHANISM EVALUATION CRITERIA ANALYSIS

R5 - Imposed Shear Stress/Imposed Tensile Stress

- τ = Force/$A_{surface}$; σ = Force/$A_{cross\text{-}section}$
- Per Spec. criteria of 100$\#_f$ shear/linear ft yields 8.33 $\#_f$/in, or, with 0.65D cable — equals 8.33$\#_f$/(in. x π x .65 Dia) or 4.08 psi.
- Per Cable Analysis, Appendix G. The modulus of elasticity measured equals 17,882$\#_f$/in^2 for a load of 100$\#_f$ and an elongation of .2003 in. over an 11.88 inch test specimen. This yields an ε of .0169 in/in.

Linear Traction: τ = 4.08 psi; σ_t = 9047 psi

Analogy - BRA-18 (Double Belt w/Clamps). Refer to Appendix A.

- 2 point loading
- 100$\#_f$/linear ft yields τ = 4.08 psi
- 3000$\#_f$ dyn. loading yields σ_t = 9047 psi
- *No bending contribution to* τ
- μ est @ .5; τ_c = 2 x σ reqd.

Clamp Traction: $\tau = 2.45$ psi; $\sigma_t = 9047$ psi

Analogy - Pultrusion, Mechanical. Refer to Appendix B.

- 4 point loading
- $400\#_f/2$ linear ft yields $\tau = 8.16$ psi

  $\sigma_C = 1332\#_f$ preload/24.504 in^2 = 54.36 psi

  as this is 6.66 x > 8.16 psi (above)

  assume $\tau_{equiv} = 16.32/6.66 = 2.45$ psi
- $3000\#_f$ dyn. loading yields $\sigma = 9047$ psi
- No bending contribution to τ
- $\mu_{est\ reqd}$ @ .333

Single Drum Capstan: $\tau = 7.35$ psi; $\sigma_t = 9047$ psi

Analogy - BRA-24 Single Drum Capstan and CHETSA. Refer to Appendix C.

- 1 point loading
- $100\#_f$/linear ft yields $\tau = 4.08$ psi
- $3000\#_f$ dyn. loading yields $\sigma = 9047$ psi
- Cal. of bending contribution to $\tau = dr/ds = .65/48 = .0135 =$ 1.35% elongation
- Present BRA-24 τ equiv = $419.5\#_f/24.504$ in^2

  = 17.12 psi or, $\approx$ <u>2.33X</u> !

  Per cable analysis, Appendix G,

  @ $100\#_f$ loading, $\varepsilon = .0169$ in/in

  $\therefore$ equivalent load = $.0135/.0169 \times 100\#_f$ or $80.1\#_f$

  $\therefore$ τ equivalent = 408 psi + $\frac{80.1\#_f}{100\#_f}$ (408 psi) = 7.349 psi
- $\mu_{est\ reqd}$ @ .188. Ref. Capstan Characterization, Appendix I

Laminar Fluid: $\tau = 2.04$ psi; $\sigma_t = 9047$ psi

Analogy - Pultrusion, Fluidic. Refer to Appendix D.

- Uniform loading
- 50# $_f$/linear ft yields $\tau = 2.04$ psi
- 3000#$_f$ dyn. loading yields $\sigma = 9047$ psi
- No bending contribution to τ
- $\mu_{\substack{est \\ reqd}}$ - not applicable

Direct Windup:* $\tau = 4.08$ psi; $\sigma_t = 9047$ psi

Analogy - AN/SQR-19. Refer to Appendix E

- 1 point loading
- 100#$_f$/linear ft yields $\tau = 4.08$ + bending contribution (see Single Drum Capstan) or $\tau_{equiv} = 7.349$ psi
- 3000#$_f$ dyn. loading yields $\sigma = 9047$ psi
- $\mu_{\substack{est \\ reqd}}$ - not applicable
- Requires additional mechanism to assist in deployment -- est @ 400 → 600#$_f$.

<u>R9, 10, 11 & 14</u> - <u>Cable Size Capability</u>

- Cable dia equals 0.650 ± .020 in. (R14)
- Inline conn., elect. and housing conns., per D-02386, 7 & 8-001. Max. 6' Lg x 1" OD; min. 12" lg x .65 OD (R9)
- Cable const. similar to NUSC Spec. C-342/4141-279 (R10)
- Antenna lements Max. 6' Lg x 6" OD; Min. 4' Lg x 4" OD (R11)
- Add'l Considerations: (Peak values - <u>All</u> <u>Mechanisms</u>)

  (a) No. longitudinally rigid connector structure elements > 6½"/2 = 3.25 in.

(b) τ_{Limit} 7.35 psi; $\sigma_{t_{limit\ cable}}$ ≥ 9047 psi;

$\tau_{c_{limit\ cable}} = 54.6$ psi

(c) Point contact loading, 4" element $< 207\#_f$

Point contact loading, 65" cable $\leq 46\#_f$

Point contact loading, .65" connectors $\leq 541\#_f$

Linear Traction

Refer to Appendix A; .65 → 4.00 in.

Clamp Traction

Refer to Appendix B; .65 → 4.00 in.

Single Drum Capstan

Refer to Appendix C; .65 → 4.00 in.

Laminar Fluid

Refer to Appendix D; .65 → ? (4.00 in. may be possible!)

Direct Windup

Refer to Appendix E; .65 → 4.00 in.

<u>R16</u> - <u>Dynamic Load Capability</u>

- Per spec. criteria, equals $3000\#_f$ minimum

Linear Traction

Refer to Appendix A; $3000\#_f$

Clamp Traction

Refer to Appendix B; $3000\#_f$

Single Drum Capstan

Refer to Appendix C; $3000\#_f$

Laminar Fluid

Refer to Appendix D; $3000\#_f$

Direct Windup

Refer to Appendix E; $3000\#_f$

R13 - Static Load Capability

- Max. static tensile $10{,}000\#_f$; Min. equals $6{,}000\#_f$
- Consideration: non-operational, steady-state towing

Linear Traction

Per Appendix A; staging required, necessitates coordination or uniform locking, i.e., $N^{\underline{o}}$.locks equals $N^{\underline{o}}$. of stages. A single lock would see loading equal to $N^{\underline{o}}$. stages x greater than operational loading.

Conclusion: locking of the traction belt(s) not recommended — therefore must lock the storage assembly.

Clamp Traction

Per Appendix B; each stage incorporates inherent regenerative braking equivalent to 3.33 x dyn. loading, or $10{,}000\#_f$.

Single Drum Capstan

Per Appendix C; pawl locking mechanism required to minimize cable burying on the storage assembly under high static loads.

Laminar Fluid

Per Appendix D; no locking capability, therefore, must lock the storage assembly.

Direct Windup

Per Appendix E; must lock the storage assembly.

R15 - FPM Capability

- Minimum speed equals 200 FPM

Linear Traction

Refer to Appendix A; 200 FPM

Clamp Traction

Refer to Appendix B; 200 FPM

Single Drum Capstan

Refer to Appendix C; 200 FPM

Laminar Fluid

Refer to Appendix D; 200 FPM

Direct Windup

Refer to Appendix E; 200 FPM

R20 - HP Required

- (a) 3000 psi @ 30 GPM = 52.5 HP
  (b) 200/440 VAC; 300/150 Amps, 3ϕ, 60 Hz = 153.3 HP
  (c) Consideration: 3000$\#_f$ dyn. loading and 200 FPM w/optimum drive selected

Linear Traction

Refer to Appendix A; 21.05

- Using a SAMM M18-80 hyd. drive motor - @ 6.5 ft-lbs/100 psi; 4.88 in.^{3}/rev, 6" PD drive sheave and idler sheave @ 128 RPM, GPM/drive belt motor equals 4.88 x 128 $\div$ 231 in.^{3}/rev = 2.704 GPM. The Δ Psi required equals 300$\#_f$ load/belt x .25 ft radius $\div$ 6.5 ft-lbs per 100 psi equals 1154 psi. HP/drive belt motor equals 2.7046 psi x 1154 psi - : 1714 = 1.821 HP.

  $\therefore$ For 2 drive belt motors/stage x 5 Stages, Net HP_{reqd} @ η_o = .865 equals 21.05.

Clamp Traction

Refer to Appendix B; 21.05

- Using 1 in. bore cyl., .65 dia. rod, 24 in. stroke x 100 strokes/min; 8 stages and 100$\#_f$/clamp (=2 ft long) x 4 clamps/stage.

  GPM_{reqd} = 146.95; Δ Psi_{reqd} = 212.06

  $\therefore$ @ an η_o = .865 equals net HP_{reqd} = 21.05

Single Drum Capstan

Refer to Appendix C; 21.05

- Using a Hagglunds 3160 hyd. drive motor - @ 275 ft-lbs/100 psi; 207 $in.^3$/Rev w/48" PD capstan drive drum rotating @ 15.92 RPM

  $GPM_{reqd} = 14.3$; $\Delta\ Psi_{reqd} = 2182$

  $\therefore$ @ an $\eta_o = .865$ equals net HP_{reqd} 21.05

Laminar Fluid

Refer to Appendix D; 72.02 or Viewgraph 2156

- Note: HP_{reqd} is directly a function of cable OD, tube ID! Unit sized for $3000\#_f$ dyn. loading, w/drag coefficient $C_D = 6.57$; Drag Force = $50\#_f$/Linear Ft. Reynolds No. of viscous fluid = 0.0408; Hyd. dia. = 2.0 for Cable OD = 0.65 in. @ an Absolute Flow Vel. = 9.33 ft/sec, relative flow vel. = 6.00; <u>Average</u> Flow = 57.21 GPM; Δ PSI/ft head loss = 33.2; 60 ft tube length equals a net HP_{reqd} @ $\eta_o = .865$ 72.02

Direct Windup

Refer to Appendix E; 21.05

- Identical characteristics to that of the single drum capstan drive.
- Additional deployment aid not included as deployment initial loads << 21.05 HP.

<u>Number of Components</u>

- Consideration: To develop means to evaluate inherent reliability and development/operating and support cost basis.

- Staging determines total number indicated as a multiple of the base configuration.
- Source energy transformer(s)/additional transfer mechanism aids not considered.

Linear Traction

Refer to Appendix A; 390

- 78 Components/Stage x 5 Stages = 390

Clamp Traction

Refer to Appendix B; 664

- 83 Components/Stage x 8 Stages = 664

Single Drum Capstan

Refer to Appendix C; 74

- 74 Components/Assembly

Laminar Fluid

Refer to Appendix D; 4

- Single tube 60 ft lg, w/dir./flow control - Pressure compensated valve (servo operated); and end seal assemblies

Direct Windup

Refer to Appendix E; 61

- Drum, Support Bearings, Drive Motor, and Levelwind Mechanism w/Ball Screw Assembly, Support Bearings, Pulleys, Timing Belt, and End Support Flanges
  (NOTE - An additional mechanism must be added to aid in deployment. Assume a *single stage traction belt* @ 48 components/stage)

R20 - Power Source Required

- Drive characterization determines source required, i.e., either electric or hydraulic.
- Consideration: Energy source transformers specified where necessary to meet drive unit requirements.

Linear Traction Belt: Hydraulic

Refer to Appendix A;

- 75 ft-lbs del. torque @ 128 RPM required. Direct-coupled to eliminate noise generators.
- Hyd. motors most efficient drive units with respect to specific vol and wt per unit del. HP.

Clamp Traction: Hydraulic

Refer to Appendix B;

- Functional configuration requirements/required loads, dictate hyd. cylinders.
- Energy source transformer required to convert ship source power by inverting GPM-PSI relationship.

Single Drum Capstan: Hydraulic/Electric

- 6000 ft-lbs Del. torque @ 15.92 RPM required.
  Direct-coupled to eliminate noise generators.
- Hyd. Motor - 1 ea. Hagglunds 3160
- Solid State Drive - 7 ea PMI
  Torque Ring 4/2.5 @ 880 ft-lbs (continuous)
  (Pressure compensated version could reduce N$^{\underline{o}}$. required to 2 ea.
  i.e., 19.4 ft-lbs/Amp yields 90.72 Amps w/DC of Approx. 170_{max} (Est. Only.)
  ∴ kw = I x V = 15.42 kw
  & 4 ea. Motors = 61.68 kw

- Energy source transformer required to convert ship source electric power from 220/440 VAC, 300/150 Amps, 3Ø, 60 Hz to a DC Power Supply or use ships DC bus.

Laminar Fluid: Electric

- Special Fluid Required having 3049$\#_m$/ft-sec Absolute Viscosity @ 85^{o}F
- Energy source transformer required to convert ship source electric power to electric/hydraulic prime mover such as IMO or SIMPLEX recirculation pump

Direct Windup: Hydraulic/Electric

- Identical characteristics to that of the single drum capstan

<u>R7</u> - <u>Envelope</u>

- Based upon Min/Max analysis, with values selected accurate to ranges indicated.
- Based upon 3000$\#_f$ Dyn. Load and 200 FPM requirements with antenna element capacity up to 4 in.

Linear Traction

Refer to Appendix A; 32.02 $\pm$ 10%

Clamp Traction

Refer to Appendix B; 34.30 $\pm$ 10%

Single Drum Capstan: 25.21 $\pm$ 10%

Refer to Appendix C; 25/21 $\pm$ 10%

Laminar Fluid

Refer to Appendix D; 9.90 $\pm$ 10%

- Does not include weight required for Energy Source Transformers. Refer to R20 for Discussion.

Direct Windup

Refer to Appendix E; 86.54 ± 10%

- Does not include weight required for Energy Source Transformers. Refer to R20 for Discussion.

R19 - Weight

- Based upon Min/Max analysis with values selected accurate to range indicated
- Based upon 3000$\#_f$ dyn. load and 200 FPM requirements, with antenna element capacity up to 4 in.

Linear Traction

Refer to Appendix A; 1500# ± 10%

Clamp Traction

Refer to Appendix B; 1814 → 2000#

- Required lightweight technology application to achieve 226.8# + 23.2#/Stage x 8 Stages — yields 1814 → 2000#
- Does not include weight required for Energy Source Transformer. Refer to R20 for Discussion.

Single Drum Capstan

Refer to Appendix C; 2300# ± 10%

Laminar Fluid

Refer to Appendix D; 1483.1 → 1779.8#

- 1483.1 ± 2% yields a range of 1483.1 → 1779.8#
- Does not include weight required for Energy Source Transformer. Refer to R20 for Discussion.

Direct Windup

Refer to Appendix E; 2896# ± 10%

Inherent Reliability

- Based upon FARADA Shipboard Equipment Failure Rate Data - Control Components/Valving excluded
- Analogous components/generalizations employed to ascertain relative MTBF comparisons. (Series Analysis employed)

Linear Traction

Items/Stage	No. Reqd.	$\lambda/10^6$ Hrs.	λ Net/10^6 Hrs.
a. Main Bearings	8	93.2	745.6
b. Idler Bearings	14	93.2	1304.8
c. Belts-4" wide	2	3125.0	6250.0
d. Hyd. Motors	2	167.0	303.0
e. Gripping Attach.	242	1.0	242.0
f. Timing Chains	2	347.0	694.0
g. Hyd. Actuators	4	667.0	2668.0
h. Stage Support Str.	2	0.1	.2
			12,207.6

$$\text{STAGE MTBF}_{est} = \frac{1}{\Sigma\lambda_i} = \frac{1 \times 1^6 \text{ Hrs.}}{12{,}207.6 \text{ Failures}}$$

$$= \underline{81.82} \text{ Hrs.}$$

- Assuming an R&D optimization of the following items:

  (a) & (b) Change to Kamatics Bushings @ > 100, 730 Hrs MTBF or select appropriate B_{10} @ 10X

  (c) LC-54 belt configuration @ = > 1000 Hrs MTBF

  (d) SAMM hyd. motors, actual = > 12,000 Hrs MTBF

  (e) Timing chains to > 6000 Hrs MTBF

  (f) Hyd. actuators to > 6000 Hrs MTBF

  (g) No change

$$\text{STAGE MTBF}_{adj} = \frac{1}{\Sigma\lambda_{adj}} = \frac{1 \times 10^6 \text{ Hrs}}{3697.1 \text{ Failures}}$$

$$= \underline{270.5} \text{ Hrs}$$

- Conclusion: (a) Belt replacement mandatory approximately every 250 operating hrs. to assure that the system remains operational. An adjusted $MTBF_{est}$ assuming belt maintenance yields:

$$\therefore \quad \text{STAGE MTBF}_{adj.} = \frac{1}{\Sigma\lambda_{adj.}} = \frac{1 \times 10^6 \text{ Hrs.}}{2134.9 \text{ Failures}}$$

$$= \underline{468.4} \text{ Hrs}$$

$$\& \text{ SYSTEM MTBF} = \frac{1}{\Sigma\lambda_{STAGE}} = \frac{1 \times 10^6 \text{ Hrs}}{10{,}674.5 \text{ Failures}}$$

$$= \underline{93.7} \text{ Hrs}$$

Clamp Traction

	Items/Stage	No. Reqd	$\lambda/10^6$ Hrs.	λ Net/10^6 Hrs.
a.	Tube	1	.1	1.0
b.	Clamp Support Hsg.	4	.5	2.0
c.	T&B Linkage Members	8	10.0 est	80.0
d.	Linkages	16	20.0 est	320.0
e.	Hyd. Actuators	8	166.7*	1333.6
f.	Flanges	2	.1	.2
				1736.8

*Refer to previous analysis for Traction Belt optimization.

$$\therefore \quad \text{STAGE MTBF} = \frac{1}{\Sigma \lambda_i} = \frac{1 \times 10^6 \text{ Hrs}}{1736.8 \text{ Failures}}$$

$$= 575.8 \text{ Hrs.}$$

$$\& \text{ SYSTEM MTBF} = \frac{1}{\Sigma \lambda_{STAGE}} = \frac{1 \times 10^6 \text{ Hrs}}{13.894.4 \text{ Failures}}$$

$$= \underline{72.0} \text{ Hrs.}$$

Single Drum Capstan

	Item	No. Reqd	$\lambda/10^6$ Hrs.	λ Net/10^6 Hrs.
(a)	Drum	1	.1	.1
(b)	Bearing Supports	2	.1	.2
(c)	Bearings	2	9.3*	18.6
(d)	Hyd. Motor	1	83.3*	83.3
(e)	Shaft w/Mts	1	.1	.1
(f)	Pinch Roller Supports	2.5	.1	.5
(g)	Pinch Roller Assys. (analogy - 2x Linkages)	60	20.0 est	1200.0
				1302.7

$$\therefore \quad \text{SYSTEM MTBF} = \frac{1}{\Sigma \lambda_i} = \frac{1 \times 10^6 \text{ Hrs.}}{4902.8 \text{ Failures}}$$

$$= \underline{768.0} \text{ Hrs.}$$

Laminar Fluid

	Item	No. Reqd	$\lambda/10^6$ Hrs.	λ Net/10^6 Hrs.
(a)	Tube	1	.1	.1
(b)	Dir. F.C. Vlv.	1	417.0	417.0
(c)	End Seals	2	356.0	712.0
				1129.1

$$\therefore \quad \text{SYSTEM MTBF} = \frac{1}{\Sigma \lambda_i} = \frac{1 \times 10^6 \text{ Hrs.}}{1129.1 \text{ Failures}}$$

$$= 885.7 \text{ Hrs.}$$

Direct Windup

	Item	No. Reqd	$\lambda/10^6$ Hrs.	λ Net/10^6 Hrs.
(a)	Drum	1	.1	.1
(b)	Support Brgs	2	9.3*	18.6
(c)	Drive Motor	1	83.3*	83.3
(d)	Ball Scw	1	347.0	347.0
(e)	Support Brgs		9.3*	18.6
(f)	Pulleys/Gears	2	160.0	320.0
(g)	Timing Belt/Chain	1	347.0	347.0
(h)	Support Flgs	2	.1	.2
(i)	Deployment Aid, Single Stage Traction Belt (or equivalent)	1	2134.9*	2134.9
				3269.7

$$\therefore \text{ SYSTEM MTBF } = \frac{1}{\Sigma\lambda_i} = \frac{1 \times 10^6 \text{ Hrs.}}{3269.7 \text{ Failures}}$$

$$= \underline{305.8} \text{ Hrs.}$$

Development Cost

- Tabulation of Criteria: (= Σ Multiples)
  - (a) 3 x Base Hardware Cost for Prototype Model Des.
  - (b) 2 x Base Hardware Cost for Optimization Reqd (R&D)
  - (c) 1.5 x Base Hardware Cost for Shop Fab. Dwgs.
  - (d) 1.0 x Base Hardware Cost for Prototype Model Hdwe.
- Above factors adjusted for % of Total Required

*Ref. Linear Traction Stage

Linear Traction:

•	Base Hardware Cost Est. @ $24,000 x 3	=	$ 72k
•	R&D Required -- x 2	=	48k
•	Shop Fab. Dwgs. Required x 1.5	=	36k
•	Prototype Model Hardware Required x 1.0	=	24k
			$180k

Clamp Traction:

•	Base Hardware Cost Est. @ $23,800 x 3	=	$ 71.4k
•	R&D Reqd -- x 3 (No existing R&D)	=	71.4k
•	Shop Fab. Dwgs. Required x 1.5	=	35.7k
•	Prototype Model Hardware Reqd x 1.0	=	23.8k
			$202.3k

Single Drum Capstan:

•	Base Hardware Cost Est. @ $22,700 x 3	=	$ 68.1k
•	R&D Reqd -- x 1 (Existing R&D avail.)	=	22.7k
•	Shop Fab. Dwgs. Required x 1.5	=	22.7k
•	Prototype Model Hardware Reqd x 1.0	=	22.7k
			$136.2k

Laminar Fluid:

•	Base Hardware Cost Est @ $8k x 3 ($6 → 12k) range	=	$ 24.0k
•	R&D Reqd -- x 5 (No existing R&D)	=	40.0k
•	Shop Fab. Dwgs. Reqd x 0.5 (very simple)	=	4.0k
•	Prototype Model Hardware Reqd x 1.0	=	8.0k
			$ 76.0k

Direct Windup:

• Base Hardware Cost Est. @ $26,700 x 3	=	$ 80.1k
• R&D Reqd -- x 1 (Existing R&D avail.)	=	26.7k
• Shop Fab. Dwgs. required x 1.5	=	40.1k
• Prototype Model Hardware Reqd x 1.0	=	26.7k
		$172.6k

R8 - Maintainability/Accessibility

- Considerations: (1) Staging as required for removal/repair and replacement; (2) Simplicity -- Standardized components; (3) Function of Envelope and Weight; (4) Accessibility within the Pressure Hull; (5) Required Tooling/Maintenance Equipment; and (6) Inherent Reliability
- Most significant factor, (6), to be weighed @ 2x

Linear Traction:

Consideration		Value Earned
(1)	Has staging	+1
(2)	Standardized	+1
(3)	Ranked 3rd Vol & 1st wt	+1
(4)	Long and slender	+1
(5)	Equipment required is very high	0
(6)	Ranked 4th by MTBF	0
		4.0

Clamp Traction:

Consideration		Value Earned
(1)	Has staging	+1
(2)	Standardized	+1
(3)	Ranked 3rd vol and 3rd wt	+1
(4)	Long and slender	+1
(5)	Equipment required is med	0
(6)	Ranked 5th by MTBF	0
		4.0

Single Drum Capstan:

Consideration		Value Earned
(1)	P.R. Assemblies staged	+1
(2)	Standardized	+1
(3)	Ranked 2nd vol and 4th wt	0
(4)	Very bulky	0
(5)	Equipment required is low	+1
(6)	Ranked 2nd by MTBF	+2
		5.0

Laminar Fluid:

Consideration		Value Earned
(1)	Only end seals	+1
(2)	Standardized	+1
(3)	Ranked 1st vol and 2nd wt	+1
(4)	Long and very slender	+1
(5)	Equipment required is very low	+1
(6)	Ranked 1st by MTBF	+1
		7.0

Direct Windup:

Consideration		Value Earned
(1)	Separable levelwind	+1
(2)	Standardized	+1
(3)	Ranked 5th vol & 5th	0
(4)	Narrow profile	+1
(5)	Equipment required is low	+1
(6)	Ranked 3rd by MTBF	+2
		6.0

Cable Contact Efficiency

- Consideration: Evaluation of potential impact upon Buoyant Cable and Atenna Element Characteristics: (1) Point Contact; (2) Circumferential Contact; (3) σ_c required

Linear Traction:

Consideration		Value Earned
(1)	2-Point	+ .5
(2)	Modified Circumferential	+ .5
(3)	8-16 psi (ok)	+1.0
		2.0

Clamp Traction:

Consideration		Value Earned
(1)	4-Point	+1.0
(2)	Full Circumferential	+1.0
(3)	σ_c = 54.36 psi (ok)	1.0
		3.0

Single Drum Capstan:

Consideration		Value Earned
(1)	1-Point	0
(2)	No Circumferential	0
(3)	2.66 psi_{est} (ok)	+1.0
		1.0

Laminar Fluid:

Consideration		Value Earned
(1)	4-Point +	+1.0
(2)	Full Circumferential	+1.0
(3)	$\sigma_c = \Delta \overline{PSI}$ 1000 psi (best)	+1.0
		3.0

Direct Windup:

Consideration		Value Earned
(1)	1-Point	0
(2)	No Circumferential	0
(3)	2.66 psi_{est} (ok)	+1.0
		1.0

Friction Dependence

- Consideration: Evaluation of sensitivity to environmental degradation of performance

Linear Traction Belt

Refer to Appendix A; $\mu = 0.5$

Clamp Traction

Refer to Appendix B; $\mu = .33$

Single Drum Capstan

Refer to Appendix C; $\mu = .19$

Laminar Fluid

Refer to Appendix D; $\mu = .002$

- Avg σ_c = 1000 psi; generates $50\#_f$ per 24.50 in.^{2} 2 psi or coupling efficiency @ .002

Direct Windup

Refer to Appendix E; $\mu = .19$

<u>Fatigue/Wear Impact</u>

- Consideration: Evaluation of potential impact upon Buoyant Cable and Antenna Characteristics: (1) Flexure Required; (2) Scuffing Required; (3) Cable Snap

Linear Traction:

Consideration	Value Earned
(1) No Flexure	+1.0
(2) No Scuffing	+1.0
(3) No Snap	+1.0
	3.0

Clamp Traction:

Consideration	Value Earned
(1) No Flexure	+1.0
(2) No Scuffing	+1.0
(3) No Snap	+1.0
	3.0

Single Drum Capstan:

Consideration	Value Earned
(1) Flexure	0
(2) Scuffing	0
(3) No Snap	+1.0
	1.0

Laminar Fluid:

Consideration		Value Earned
(1)	No Flexure	+1.0
(2)	No Scuffing	+1.0
(3)	No Snap	+1.0
		3.0

Direct Windup:

Consideration		Value Earned
(1)	Flexure	0
(2)	No Scuffing	1.0
(3)	Snap	0
		1.0

R3 - Structureborne Noise/Airborne Noise

- Consideration: Evaluation of inherent structureborne noise generation. Refer to Analysis Appendix F.

Linear Traction

Allowable Amplitude equals .00245 in. Will meet Spec., ± 3 AdB uncertainty, to meet or exceed specification.

Clamp Traction

Allowable Reciprocating imbalance @ 0.25%. Will meet Spec., + AdB uncertainty, to meet or exceed specification.

Single Drum Capstan

Allowable Amplitude equals .159 in. Will meet Spec., @ + 3 AdB margin, to be below specification.

Laminar Fluid

Only noise source due to Fluid-borne transmission. Will meet Spec. @ >> 3 AdB margin, to be below specification.

Direct Windup

Allowable Amplitude equals .159 in. Will meet Spec. @ > 3 AdB margin, to be below specification.

- Consideration: Evaluation of estimated airborne noise generation. Refer to Appendix F, for comparison of specification requirements.
- Experience with identical hydraulic motors, recommended for DRSS, and utilized on the CHETSA development program indicate the following:

(1) The ship's hydraulic power supply/operating pressure is the fundamental critical factor in being capable of meeting the airborne noise criteria. Additionally, fluid velocity/fluid shear effects thru valves/restrictions as a function of Δ PSID operating, are a function of the sixth or seventh power of velocity in noise generation.

(2) Low RPMs of hydraulically powered machinery; line/flow path sizing to effect a < 3 FPS flow velocity, and employment of hydraulic motors (i.e., Hagglunds 3160 @ < 8% of maximum rated speed and SAMM M18-80 @ < 17% of maximum rated speed, assure minimum airborne noise generation. (A doubling of speed from 200 FPM to 400 FPM could add 36.1 dBs to the noise generation contribution of the fluid flow/shear effects.)

(3) Utilizing the above considerations, it is felt that all mechanisms can meet the airborne noise specification requirements, with the following predicted ranking.

Linear Traction: (@ 128 RPM) - barely meet

Clamp Traction: (@ 60 CPM) - barely meet

Single Drum <u>Capstan:</u> (@ 15.92 RPM) - significantly below spec.

Laminar Fluid: (@ 9.33 ft/sec) - below spec.

Direct Windup: (@ 21.22 RPM) - significantly below spec.

R6 - Installation Compatibility

- Consideration: Must be within the confines of the existing superstructure of the SSN-637, 688 class and compatible with SSBN submarines.
- All Mechanisms analyzed appear to meet the minimum requirements of % of the total allowed Vol (R7) and Wt (R19), with the Direct Windup being marginal.

Producibility

- Consideration: Must be able to fabricate and assemble to the tolerances required, employ available materials, employ minimum number of components and qualification tested.
- Ranking as follows: 1 - Low Difficulty; 2 = Medium Difficulty; and 3 = High Difficulty

  Linear Traction: 2 → 3

  Clamp Traction: 3

  Single Drum Capstan: 2

  Laminar Fluid: 1

  Direct Windup: 1 → 2

G1 - Variable Diameter

- Consideration: 0.50 → 1.0 Dia. Capability

  All Mechanisms appear capable of meeting this cable variability.

G3 - $6000\#_f$ Dynamic Load

- Consideration: A single asterisk indicates staging Requirements must be impacted with respect to R7 and R19. A double asterisk indicates pressure limitation. A triple asterisk indicates a HP related Power Source potential limitation.

  Linear Traction Belt: $6000\#_f$ *,**,*** Clamp Traction: $6000\#_f^{*}$

Single Drum Capstan: $6000\#_f^{**,***}$

Laminar Fluid: $3000\#_f$ (Does not meet)

Direct Windup: $6000\#_f^{**,***}$

G2 - 400 FPM Capability

- Consideration: A single asterisk indicates speed limitation with respect to Noise Generation. A double asterisk indicates a HP related Power Source potential limitaiton.

  Linear Traction: 400 FPM*

  Clamp Traction: 400 FPM*

  Single Drum Capstan: 400 FPM**

  Laminar Fluid: 200 FPM (Does not meet)

  Direct Windup: 400 FPM**

5.2 CABLE STORAGE EVALUATION CRITERIA ANALYSIS

R1 - Positive Self-Sealing:

- Imposed on the RF interface only. Not defined for this study. No problems anticipated is achievement (for the RF interface - slip ring configuration).
- Not depicted on the Tradeoff Summary Charts.

R5 - Imposed Shear Stress, Tensile Stress:

CHETSA

- Refer to Appendix J - 9.78 psi shear
  302 psi tensile
- derived from 3 ft minimum bend radius w/criteria of Appendix I, and < $300\#_f$ tension. Shear stress is an absolute worst case!

W/Levelwind

- Refer to Appendix K - 9.78 psi shear
  3016 psi tensile
- Derived from 3 ft minimum bend radius w/criteria of Appendix I, and < 1000_f tension.

PPAT

- Refer to Appendix L - 9.78 psi shear
  3016 psi tensile

  Derived from requirement for the drive train to be within the PPAT — assuming $1000\#_f$ capability and a minimum bend radius of 3 ft (to assure minimum envelope requirements).

Barrel Stuffing

- Refer to Appendix M - ≤ 1.02 psi shear
  ≤ 100 psi tensile
- Estimate only, probably lower! Assume < $25\#_f$/linear ft and < $100\#_f$ net tensile loading.

R16 - Dynamic Load Capability:

CHETSA

- Refer to Appendix J: $300\#_f$
- Based upon a maximum allowable storage tension approximately 3X greater than the existing CHETSA development program requires. This provides a margin of safety to assure that the Antenna Elements 4" OD x 4' long can be wrapped 'snug' for storage -- yet keep point-contact loading (compression/deformation) well below critical limits.

W/Levelwind

- Refer to Appendix K: $1000\#_f$
- Based upon the assumption that a Deploy/Retrieve Mechanism is required. $1000\#_f$ is a best estimate of achievable capability without imposing severe cable handling forces on the B.C.A. Also refer to Section 1, Para. 1.2.4 Recommendations.

PPAT

- Refer to Appendix L: 1000#
- Allocation from $3000\#_f$ total required, to the Storage Assembly, as an achievable capability. Note that a Deploy/Retrieve mechanism is required.

Barrel Stuffing

- Refer to Appendix M: $100\#_f$
- Estimate only, of maximum imposed tensile load on the buoyant cable assembly.

R13 - Static Load Capability:

CHETSA

- Refer to Appendix J: $10{,}000\#_f$

- Although capable of $10{,}000\#_f$, caution must be made - due to possible cable burying effect. Note that $10{,}000\#_f$ is generated at maximum scope deployed, high ship speed, implying very few wraps or layers remaining on the barrel. Compression/deformation -- assuming no crossover (overwrap) the loading could be sustained by employment of a LeBus barrel. Note that the Storage Assembly is not the ideal location for introduction of static load holding capability.

W/Levelwind

- Refer to Appendix K: 10,000#
- See above discussion

PPAT

- Refer to Appendix L: 10,000#
- See above discussion

Barrel Stuffing

- Refer to Appendix M:
- No capability

R15 - FPM Required: 200 FPM

All mechanisms are capable of achieving the required inhaul/outhaul speed.

R20 - HP Required:

CHETSA

- Refer to Appendix J - 2.06 HP

W/Levelwind

- Refer to Appendix K - 6.85 HP

PPAT

- Refer to Appendix L - 6.85 HP

Barrel Stuffing

- Refer to Appendix M - <1 HP

R20 - Power Source Required:

Hydraulic/Electric

- All mechanisms are amenable to integration of either hydraulic or electric drivers.

R7 - Envelope Required:

CHETSA

- Refer to Appendix J - 42.85 ft^3

W/Levelwind

- Refer to Appendix K - 70.13 ft^3

PPAT

- Refer to Appendix L - > 85.0 ft^3

Barrel Stuffing

- Refer to Appendix M - 110, 25 ft^3
- *atmosphere vs free flood displacement*

R19 - Weight Required:

CHETSA

- Refer to Appendix J - $1887\#_m$

W/Levelwind

- Refer to Appendix K - $1613\#_m$

PPAT

- Refer to Appendix L - $>6000\#_m$

Barrel Stuffing

- Refer to Appendix M - $1336\#_m$

Number of Components

CHETSA

- No. of Components Appendix J - 6

W/Levelwind

- No. of Components Appendix K - 13

PPAT

- No. of Components Appendix L - 14

Barrel Stuffing

- No. of Components Appendix M - 6

Inherent Reliability, MTBF:

CHETSA

- Refer to Appendix J - >10,000 Hrs
- Direct extrapolation of CHETSA development program

W/Levelwind

- Refer to Appendix K - >5000 Hrs
- Direct extrapolation of AN/SQR-19 development programs

PPAT

- Refer to Appendix L - >2,500 Hrs.
- A very generous allocation -- at least 4X less reliable than CHETSA.

Barrel Stuffing

- Refer to Appendix M - > 5,000 Hrs.
- Potentially as reliable as the CHETSA Concept, but speed synchronization-control/feedback - dictates a 2X reduction in reliability as a best estimate.

Developmental Cost:

- Note - does not include assembly or test certification!
- Tabulation of Criteria: (= Σ Multiples)
- If employ PMI Solid State Torque Ring Drive, add $25-75k
  - (a) 3X Base Hardware Cost for Prototype Model Design
  - (b) 1 → 2X Base Hardware Cost for R&D required
  - (c) 1 → 2X Base Hardware Cost for Shop fabrication drawings

(d) 1X Base Hardware Cost for Prototype Model Hardware

CHETSA

- From Appendix J - B.H.C. = $20.667 (estimated)
- (3 + 1 + 1 + 1) X BHC = $124k

W/Levelwind

- From Appendix K - B.H.C. = $28,860 (estimated)
- (3 + 1.5 + 1.5 + 1) X B.H.C. = $202k

PPAT

- From Appendix L - B.H.C. = $46,250 (estimated)
- $3 + 2 + 2 + 1) X B.H.C. = $307k

Barrel Stuffing

- From Appendix M - B.H.C. = $31,077 (estimated
  where cost of Divertor Value w/injector assembly included
  in the total
- (3 + 1 + 1.5 + 1) X B.H.C. = $202k (estimated)

R8 - Maintainability/Accessibility:

Inherent Reliability, -- No. of elements requiring repair/replacement; Simplicity -- Standardized components; Function of Envelope & Weight, and/or accessibility within the pressure hull.

CHETSA: 3 & 3

Based upon relative comparison to other three concepts -- highest ratings

W/Levelwind: 3 & 2

Based upon relative comparison to other three concepts -- similar to CHETSA but levelwind increases the degree of difficulty re-accessibility

PPAT: 2 & 1

Environmental aspects increase potential maintainability requirements. Accessibility is very difficult.

Barrel Stuffing: 1 & 1

Inaccessible; non-maintainable -- similar to PPAT -- as location in Aft ballast tank

Cable Contact Efficiency:

CHETSA

- Refer to Appendix J: 1 Point
- By inspection

W/Levelwind

- Refer to Appendix K: 2 Point
- By inspection, employs levelwind

PPAT

- Refer to Appendix L: 2 Point
- Assumes levelwind is required to minimize envelope -- i.e., increases packaging efficiency of cable storage

Barrel Stuffing

- Refer to Appendix L: 1 Point
- Although 1 Point, extremely low imposed shear and tensile loading make this a poor comparison for this evaluation criteria

Friction Dependence:

CHETSA

- Refer to Appendix J: .021
- Analogous to Single Drum Capstan Concept discussed in Section 1 where $\mu = .19$ required to assure that shear stress of $100\#_f/ft$ is not exceeded (@ $3000\#_f$ dynamic load). Equvalent to a 9X reduction.

W/Levelwind

- Refer to Appendix K: .063
- Similar analogy @ 3X load increase

PPAT

- Refer to Appendix L: .063
- Similar analogy @ 3X load increase

Barrel Stuffing

- Refer to Appendix M: <.021
- Similar analogy @ <1X load

Fatigue/Wear Impact:

- Ranking according to imposed shear plus tensile loading, and bend radius. (3 equals least impact)

  CHETSA: 2

  Higher than Barrel Stuffing but less than w/Levelwind or PPAT.

  W/Levelwind: 1

  Highest shear and tensile loading

  PPAT: 1

  Highest shear and tensile loading

  Barrel Stuffing: 3

  Lowest shear and tensile loading

R3 - Airborne Noise/Structureborne Noise:

- RPMs, required supply pressure (if hydraulic) -- i.e., a direct function of HP required.
- 2 equals highest ranking (lowest noise)

  "CHETSA" Concept: 2

  Excellent capability to be below specified limits

W/Levelwind: 1

Good capability to be below specified limits

PPAT:

Good capability to be below specified limits

Barrel Stuffing

Excellent capability to be below specified limits

R6 - Installation Compatibility:

- Ranking according to degree-of-difficulty to install or backfit the component configuration analyzed. A function of Envelope & Weight, and assemblability.
- 3 equals highest compatibility.

CHETSA: 3

W/Levelwind: 2

PPAT: 1

Barrel Stuffing: 1.5

Producibility:

- Ranking according to degree-of-difficulty in fabrication, assembly and test certification.
- 3 equals highest producibility.

CHETSA: 3

W/Levelwind: 25

PPAT: 2

Barrel Stuffing: 1.5

The synchro-speed control adjustment (divertor valve and injector assembly coordination) could be potentially unique for each unit produced -- requiring extensive test and adjustment.

G2 - 400 FPM Capability:

All concept configurations can achieve the goal performance of 400 FPM.

G1 - Variable Diameter, 0.50 → 1.00:

CHETSA: OK

W/Levelwind:

- Cannot be employed
- The levelwind mechanism is not easily configured to accept varying diameters w/o very high increase in complexity. (The AN/SQR-19 handles a 1.1 in. OD → 3.25 in. OD cable assembly.)

PPAT:

- Cannot be employed
- Refer to above

Barrel Stuffing: OK

G3 - $6000\#_f$ Dynamic Load:

- The Storage Assembly(s) contributes capacity to handle the load -- but is not the primary means by which this capability is generated.
- Not depicted on the Tradeoff Summary Charts.

G5 - Operation/Control by One Person w/Technical Rating:

- Indeterminate. Refer to Systems Level integration and analysis, Volume I.
- Not depicted on the Tradeoff Summary Charts.

5.3 PART 1: CONDUIT/GUIDE TUBE EVALUATION CRITERIA ANALYSIS

- R4 - No impact, acceptable
- R5 - Ref. 1.2.2(h), acceptable
- R6 - Designed to be within the confines of the existing superstructure, acceptable
- R7 - Total Envelope @ 1.636 ft^3/linear running ft*
- R11 - Can accommodate a 4.0 in. OD x 4 ft long Antenna Element, acceptable
- R13 - To be designed for 1.5X B.C.A. breaking strength or $6000\#_f$, whichever is greater, acceptable
- R14 - Accommodates .650 $\pm$ .020 in. diameter B.C.A., acceptable
- R15 - Permits 200 FPM payout/retrieval speed. Refer to 1.2.2(j)
- R16 - Sustains $3000\#_f$ dynamic loading. Refer to 1.2.2(h)
- R19 - Total Weight @ $13.43\#_m$/linear running ft*
- G1 - Obviously compatible with .50 → 1.00 dia. B.C.A.
- G2 - Can sustain 400 FPM payout/retrieval speed, acceptable
- G3 - Can sustain $6000\#_f$ dynamic loading, acceptable

*Ship's structural interface must be determined in order to define overall length required.

5.3 PART 2: VALVES EVALUATION CRITERIA ANALYSIS

This is a critical program area which could not be adequately addressed during this phase. We suggest that valves definition be a high priority critical area for follow-on studies.

Preliminary concept configuration definition for both the Shear-Seal and the Clamp Seal indicates great potential to resolve valving requirements as related to the DRSS application. A further detailed definition with respect to these two new concepts - and comparison to off-the-shelf valving options is recommended.

5.3 PART 3: SEALS EVALUATION CRITERIA ANALYSIS

R1 - Positive Self-Sealing:

- All are acceptable
- All dynamic seals are failsafe to the closed position. Refer to Appendix N, P, Q, R & S.
- The manual static seal - similar to the Fixed, 2-Posn., Split Seal, per Appendix R - is acceptable

R5 - Imposed Shear Stress, Tensile Stress:

- 4.08 psi shear & $< 25\#_f$ tensile
- All dynamic seals are essentially non-contact, or assuming a viscous fluid - pressure compensated - w/wiper seal "in" and "out". This is a best estimate of achievable performance for each of the configurations.
- The manual static seal is engaged in the non-operational mode. Clamping or compression loading shall be over a 1.5 inch length of cable @ < 600 psi.

R9, 10, 11 & 14 - Cable Size Capability:

- The Articulated Seg., per Appendix P can only achieve a 2:1 cable dia. ratio.
- The Var. Bladder, per Appendix AQ, can only achieve a 2:1 cable dia. ratio.
- The Fixed 2-Posn., Split, per Appendix R, can achieve .65 → 4.0 in. cable dia.
- The Var. Iris, per Appendix S, can achieve .65 → 4.0 in. cable dia.
- The Static Seal shall be configured to seal about the smallest cable diameter and capable of opening to pass a 4.0 inch Antenna Element.

R4 - Static Load Capability:

- Δ PSI to maximum submarine operating depths
- All seals appear capable of achieving this ΔPSI capability.

R15 - FPM Capability:

- 200 FPM
- All seals are acceptable

R2 - Shear-Seal Capability:

Refer to Section 3, Part 2, for discussion of Cable/Antenna Element Shear Assembly. This assembly should be evaluated in a later study effort to ascertain whether or not the functional requirement for shearing and sealing is a desirable design concept goal.

R7 - Envelope:

- All seals are < .5 ft^3, except for Iris @ 150%
- Refer to Appendices P → S.

R19 - Weight:

- All seals are < $100\#_m$
- Refer to Appendices P → S

Number of Components:

Art. Seg.- - - - - - - - 45, Per Appendix P

Var., Bladder - - - - - 6, Per Appendix Q

Fixed, 2-Posn., Split - 8, Per Appendix R

Var., Iris - - - - - - - - 81, per Appendix S

Manual Static - - - - - 8, Per Appendix P

Inherent Reliability:

- Severity Factor Set equal to 10 for submarine operating environment and 20 for condition of material rubbing contact.

		λ x10^6HRS	Severity Factor*	Total
Art. Seg.				
32	Segments	0.50	10	160.0
1	Bellows Sent	65.43	10	654.3
5	"O" Rings - static	2.39	1	12.0
5	Hsg. Str. Elem.	-	1	-
2	Adiprene Max OD	2.39	10	4.8
45	Sealing Elem			831.1

∴ MTBF = 1203 HRS

		λ x10^6HRS	Severity Factor*	Total
Var., Bladder				
1	Bellows Diaphram	65.43	20	1308.6
1	Housing	-	1	-
2	End Flg. Assy.	-	1	-
2	"O" Rings - static	2.39	1	4.8
6				1313.4

∴ MTBF = 761 HRS

		λ x10^6HRS	Severity Factor*	Total
Fixed, 2-Posn., Split				
2	Split Clamp Assy.	-	1	-
2	Split "O" Ring Seals, Dyn.	2.39	20	96.0
2	Hyd. or Elec Actuators	10.71	10	214.2
2	"O" Rings - static	2.39	1	4.8
8				314.0

∴ MTBF = 3185 HRS

		λ x10^6HRS	Severity Factor*	Total
Var., Iris				
64	Iris Elements	.50	10	320.0
8	Hyd. or Elect. Actuators	10.71	10	856.8
8	Elem. Staging Str.	.50	10	40.0
1	Housing	-	-	-
81				1216.8

∴ MTBF = 822 HRS

Developmental Cost:

- Tabulation of Criteria: (= Σ Multiples)

  (a) 3X Base Hardware Cost for Prototype Model Design

  (b) 1 → 2X Base Hardware Cost for Optimization Reqd. (R&D)

  (c) 1 → 2X Base Hardware Cost for Shop Fab. Dwgs.

  (d) 1X Base Hardware Cost for Hardware

- Base Hardware Cost includes: Sensors, Controls, and Seal Hardware

  Art. Seg. - (2k + 2k + 10k) x (3 + 2 + 2 + 1) = $112k

  Var., Bladder - (1k + 1k + 4k) x (3 + 1.5 + .5 + 1) = $36k

  Fixed, 2-Posn., Split - (5k + .5k + 3k) x (3 + 1 + 1 + 1) = $24k

  Var., Iris - (2k + 3k + 5k) x (3 + 2 + 2 + 1 = $80k

R8 - Maintainability/Accessibility:

- Ranked on a scale of 1 (worst) to 3 (best) according to the degree of difficulty in removal, disassembly and repair.

  Art. Seg. - 1

  Var., Bladder - 3

  Fixed, 2-Posn., Split - 2

  Var., Iris - 1

Cable Contact Efficiency:

Art. Seg. - 32 Segments @ .0625 width = 2.0 in. vs. 2.042 in. cable periphery; = 98%

Var., Bladder - 100% (by inspection)

Fixed, 2-Posn., Split - 100% due to peripheral contact of the split wiper seals

Var., Iris - 90% — due to cascade configuration (8 actuators w/64 elements). Refer to layout Appendix S.

Friction Dependence:

- Ranked on a scale of 1 (worst) to 3 (best)
- All seals - except for the bladder - are non-contact or viscous fluid contact. The bladder -- in distending at a 2:1 ratio will automatically double the shear and tensile load resistance.

Fatigue/Wear Impact:

- Equals a function of contact force loading and susceptibility of cable scuffing/tearing and/or hangup during passage through the seal. Ranked on a scale of 1 (worst) to 3 (best).

  Art. Seg. - 3 (non-contact)

  Var., Bladder - 1 (potential regenerative effects cable jacket to bladder jacket!)

  Fixed, 2-Posn., Split - 3 (non-contact)

  Var., Iris - 2 (potential scuffing due to multiple elements .005 inches thk.)

R3 - Airborne Noise/Structureborne Noise:

- Ranked on a scale of 1 (worst) to 3 (best). Consideration given of noise generation due to Δ PSID seal leakage @ high fluid shear velocity.

  Art. Seg. - 1 (A .003 $\rightarrow$ .010 annular clearnace is necessary)

  Var., Bladder - 2 (due to cable pumping action)

  Fixed, 2-Posn., Split - 3 (essentially leak tight w/viscous fluid seal OR gravity drain w/small annular clearance of the wiper seals)

  Var., Iris - 1 (A .003 $\rightarrow$ .010 annular clearnace is necessary)

R6 - Installation Compatibility:

- Ranked on a scale of 1 (worst) to 3 (best)

Art. Seg. - 1 (very complex - alignment is critical due to bladder centering)

Var., Bladder - 3 (very simple)

Fixed, 2-Posn., Split - 3 (very simple)

Var., Iris - 2 (very complex - but mechanical linkages reduce alignment criticality)

Producibility:

- Consideration given to the following items; ranked 1 (worst) to 3 (best):

  (a) for Off-the-Shelf

  (b) for Fabrication/Assembly Difficulty

  (c) for Qualification Testing Requirements

  Art. Seg.: 1 + 1 + 1 = 3

  Var., Bladder: 2 + 1 + 2 = 5

  Fixed, 2-Posn., Split: 3 + 3 + 3 = 9

  Var., Iris: 2 + 1 + 1 = 4

Level I Material Control Traceability System

All seals must meet this requirement.

G1 - Variable Diameter, .50 → 1.00 inch:

- All except Fixed, 2-Posn., Split can achieve.
- The Fixed, 2-Posn., Split Seal cannot adapt to a continuously variable cable diameter. If the .50 → 1.00 inch cable is stepwise variable -- then this would pass.

G2 - 400 FPM Capability:

- All seals pass except the Var., Bladder.
- The Var. Bladder Seal is susceptible to potential regenerative effects -- cable jacket to bladder jacket.

5.4 TOW/EXIT POINT EVALUATION CRITERIA ANALYSIS

- R4 - No impact, acceptable
- R5 - Ref. 1.2.2(c) (1) and (2) -- acceptable, imposed loading
- R6 - Designed to be installed with the confines of the existing superstructure with minimum hydrodynamic drag profile impact -- acceptable
- R7 - Total Envelope is $< .84$ ft^3 -- acceptable
- R10 - Characterized in 1.2.2(c) (1) and (2) and in Appendix G -- acceptable for specified cable construction
- R11 - Characterized for 4 in. OD Antenna Element
- R13 - Characterized for 6000$\#_f$ minimum static tow load in 1.2.2(c) (1)
- R14 - Refer to 1.2.2(b) and 1.2.2(c) (2) and 1.2.2(e) -- acceptable
- R15 - Refer to 1.2.2(e) -- acceptable for 200 FPM
- R16 - Refer to 1.2.2(c) (2) -- acceptable for 3000$\#_f$ dynamic load
- R19 - Total Weight $< 150\#_m$ -- acceptable
- G1 - Compatible with .50 → 1.00 diameter cable
- G2 - Capable of permitting 400 FPM payout/retrieval cable speeds
- G3 - Capable of permitting 6000$\#_f$ maximum dynamic tensile loading
- No. of Components - 2 ea; Structural Bellmouth Assy and Kamatics Spherical Bearing
- Inherent Reliability - In excess of 10,000 Hrs MTBF (for the Bearing)
- Development Cost - 3x Base Hardware Cost - Design

  + .5x Optimization (R&D reqd)

  + .5x Shop, Fab. Drawing preparation

  + 1.0x Prototype Hardware

  As Base Hardware Cost = 5.5k,

  5.0 x 5.5k = $27.5k

- Cable Contact Efficiency - 1 point; arc-of-contact 0.53 → 90°
- Friction Dependence -Capable of operation @ $\mu > .6$
- Fatigue/Wear Impact -@ 50% of max allowable shear stress. Bend radius @ 2x > BRA-24. A 4 in. OD Antenna Element must not be on the fairing for high speed towing !
- Producibility - Low to Medium difficulty

ED

80